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June 1985

Air Pollution and Acid Rain
Report No. 19

VULNERABILITY OF SELECTED LAKES AND STREAMS IN THE MIDDLE ATLANTIC REGION TO ACIDIFICATION: A REGIONAL SURVEY

ORIGINAL

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FWS/OBS-80/40.19	Vulnerability of Selected Lakes and Streams in the Middle Atlantic Region to Acidification: A Regional Survey

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

EASTERN ENERGY AND LAND USE TEAM
Box 705
Kearneysville, West Virginia 25430

Dear Colleague:

The Eastern Energy and Land Use Team (EELUT) is pleased to provide you this report on the results of a regional survey of the chemistry of lakes and streams in the Middle Atlantic States. This study was conducted to assess the status of these waters with respect to their sensitivity to acidification. The report is the nineteenth in our series on air pollution and acid rain. Other reports previously issued in this series are listed on the inside front cover.

The extent and location of surface waters that are acidified or vulnerable to acidification were determined from a survey of 278 lakes and streams in nine Middle Atlantic States. These data were used to evaluate available models of acidification and to identify potential indicators of acidification. A companion study (FWS/OBS-80/40.15) provides similar information for the New England States.

Your suggestions or comments on this report are welcomed.

Sincerely,

R. Kent Schreiber

R. Kent Schreiber
Acting Team Leader, EELUT

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Air Pollution and Acid Rain
Report No. 19

VULNERABILITY OF SELECTED LAKES AND STREAMS IN THE MIDDLE ATLANTIC REGION TO ACIDIFICATION:

A REGIONAL SURVEY

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DISCLAIMER

Although the research described in this report has been funded in large part by the U. S. Environmental Protection Agency through Interagency Agreement No. EPA-82-D-X0581 with the U. S. Fish and Wildlife Service, it has not been subjected to the Agency's required peer and policy review and therefore does not necessarily reflect the views of the Agency. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the Federal Government. This research has been funded as part of the National Acid Precipitation Assessment Program by the U. S. Fish and Wildlife Service.

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EXECUTIVE SUMMARY

In conjunction with a similar study in the six New England States, 278 lakes and streams were sampled in the nine Middle Atlantic States (New York, New Jersey, Pennsylvania, Maryland, Delaware, Virginia, West Virginia, North Carolina, and Tennessee). Primary objectives of the study were to document the sensitivity of waters in the study area to acidification, and to test the validity of available models and classifications for predicting acidification of these waters. Waters were chosen to be relatively free of direct disturbance by human activity in their watersheds, and to be at as high an elevation as possible while maintaining representation of all geographic areas and bedrock and soil sensitivity classes. Lakes comprised 60% of the sites and streams 40%. Historical data for the same waters were gathered wherever available.

About 49% of the unpolluted, relatively undeveloped waters sampled in the nine states were sensitive to acidification on the basis of having alkalinity less than 200 µeq/l or of having underlying bedrock of low acid neutralizing capacity. Alkalinity is probably the most useful and relatively accurate predictor of sensitivity to acidification. Calcite saturation index (CSI) was highly correlated with alkalinity, and appeared to have no significant advantage as a predictor. Of the waters sampled, 32% were susceptible to acidification on the basis of having CSI greater than 3. Neither bedrock nor soil class is a particularly strong predictor of sensitivity to acidification, but bedrock class is somewhat correlated with alkalinity of Middle Atlantic States waters, while soil type is not, at least when determined from rock and soil maps presently available.

Comparison with available historical data indicated that many of the sampled waters have decreased in alkalinity in recent years. A similar decrease in pH was not noted, but this is to be expected so long as the acid neutralizing capacity (as represented by alkalinity) of most waters has not been completely depleted. However, the accuracy of the historical data could not be adequately evaluated to enable confident conclusions about temporal trends in acidification.

Few of the waters showed high concentrations of aluminum, and only one stream had aluminum above 200 µeq/l at a pH below

5.5, which is believed to be the range of toxicity to fish. However, we noted a doubling of average aluminum concentrations in waters with pH below 5, compared to waters with higher pH.

Sulfate levels (mean 227 μeq/l) found in the sampled waters were higher than those reported from some other areas where precipitation is acidic, and much higher than those from areas with nonacidic precipitation. Sulfate was not correlated with acidity, perhaps due to the relatively uniform deposition of sulfate by precipitation in the study area.

pH was correlated strongly with alkalinity, conductivity, and (negative) calcite saturation index, and weakly with calcium, magnesium, and disturbance. Alkalinity was strongly correlated with calcium, pH, conductivity, and magnesium, and weakly with sulfate, chloride, disturbance, rain pH, and (negative) elevation. Neither pH nor alkalinity was strongly correlated with aluminum, manganese, color, total organic carbon (as predicted from color), or size of waters.

Differences in water chemistry between lakes and streams were small, with streams in general being less acidic. Higher order streams had higher conductivity and pH, as expected due to their larger, more varied watersheds. Waters most affected by human disturbance had higher pH, conductivity, and chloride.

The calcium-pH model of Henriksen predicted the pH of waters in the study area reasonably well. It indicated that about 28% of the waters were acidified. Other published models and classifications (Thompson Cation Denudation Model, Altshuller and McBean, Sulfate-pH) that were tried predicted water pH poorly.

The study results indicate that a large number of relatively undisturbed waters in the Middle Atlantic States are either already acidified or are susceptible to acidification. Thus, parts of the Middle Atlantic States should be included on maps showing regions sensitive to acid precipitation. A large portion of the waters we sampled in the region have decreased in pH, alkalinity, or both in recent years.

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ACKNOWLEDGEMENTS

This study and a concurrent survey in New England were designed to be as similar as possible with respect to objectives and methods. In preparing this report we have benefited from ideas presented by the New England investigators (Terry A. Haines and John Akielaszek) in their report (Haines and Akielaszek 1983). For the sake of consistency we present our report in a format and order similar to theirs. Mr. Paul J. Rago of the Eastern Energy and Land Use Team, U. S. Fish and Wildlife Service, provided considerable data analysis, maps, and statistical advice. Funds for the study were derived in part from an interagency agreement with the U. S. Environmental Protection Agency. The U. S. Fish and Wildlife Service, Pennsylvania Fish Commission, and The Pennsylvania State University all provided financial and material support through the Pennsylvania Cooperative Fish and Wildlife Research Unit[1].

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INTRODUCTION

The precipitation that falls on the northeastern United States is highly acidic. Its pH averages about 4.2 but is often much lower (Likens et al. 1979; National Atmospheric Deposition Program 1984). Research has indicated that acidic precipitation has had profound effects on aquatic ecosystems, particularly fish, in Scandinavia (Leivestad et al. 1976), Ontario, Canada (Beamish 1976), and the Adirondack Mountains of New York (Schofield 1977). Evidence of serious effects on both aquatic and terrestrial ecosystems in the Northeast and other parts of the United States is accumulating rapidly (see Haines 1981 and Glass et al. 1982 for reviews).

The impact of acidic precipitation on aquatic ecosystems depends on a variety of climatic, geologic, topographic, morphometric, biotic, and anthropogenic factors. Even in areas where effects of acidification on lakes have been pronounced (La Cloche Lakes, Ontario, and Adirondack Mountains, New York) there are many lakes that seem unaffected, interspersed with acidified lakes. This phenomenon illustrates the need for indices of vulnerablity that can be applied to individual lakes and streams and that are sensitive to local conditions of rock, soil, and hydrology.

If regulations or legislation controlling emissions of sulfur and/or nitrogen oxides are to be sought as a means of reducing the adverse effects of acidic precipitation on ecosystems, detailed information will be required to substantiate the need for such reductions. Such information would need to include projections of the quantity of aquatic habitat that is susceptible to acidic precipitation inputs, and dose-response estimates for the effects of such inputs. Dose-response estimates will require detailed, long-term study in a variety of habitats subject to varying inputs of acidic precipitation.

The present study is an attempt to improve available estimates of the extent of vulnerable habitat by documenting the sensitivity of waters in the study area to acidification, and to determine which, if any, of the available predictors of vulnerability is most appropriate for use on these waters. The terms "sensitivity" and "vulnerability" as used in this report (and most acid rain literature) refer to no or low acid neutralizing capacity, thus the quality of being easily acidified. Existing surface water chemistry data were not satisfactory for validating these predictors. Existing data were predominantly collected in high order watersheds where soils are thick and geological complexity makes the presence of buffering materials likely, while acid precipitation is most likely to affect low order, headwater lakes and streams. Also, many existing water chemistry data sites were selected to determine the effects of human activities on water quality. Human activity makes natural chemistry difficult to ascertain, and there is almost always significant alkalinity contained in discharges from human activities (with the exception of acid mine drainage and a few other wastes). In general, human activity is concentrated in areas that were originally selected for agricultural productivity, and are thus likely to be well buffered. The most pervasive anthropogenic impact on alkalinity may be from agricultural liming (Johnson 1984). Finally, many existing water chemistry data were collected with methodology (e.g., colorimetric pH, fixed endpoint alkalinity titration) that produces inaccurate results when used in low ionic strength waters. Thus the present study was planned to collect valid present-day data on waters as unmodified as possible, located on low order watersheds, and to use best available methods for low ionic strength waters. The data collected, in addition to indicating current degree of acidification, if any, were used to evaluate several proposed indices of vulnerability.

The study was divided into two parts. The six New England States (Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and Rhode Island) were sampled and the results prepared by Dr. Terry A. Haines and associates at the U. S. Fish and Wildlife Service field station at the University of Maine in Orono, Maine (Haines and Akielaszek 1983; hereafter referred to as "the New England study"). We sampled sites in the nine Middle Atlantic States (New York, New Jersey, Pennsylvania, Maryland, Delaware, Virginia, West Virginia, and the Appalachian parts of North Carolina and Tennessee).

Virtually identical field and laboratory methods were used by the two groups, and statistical analyses of the two sets of data were similar. In general, the two reports follow a common outline.

MATERIALS AND METHODS

The following description refers to the Middle Atlantic part of the study but is generally true of the New England part as well. Methods differing significantly between the study parts are footnoted.

SAMPLING METHODS

Selection of Sampling Sites

Sites included in this study were selected from all available surface waters with respect to several criteria:

- broad geographic coverage
- bedrock acid neutralizing capacity
- soil cation exchange capacity
- location in upper portion of watershed (i.e., altitude, stream order)
- absence of direct human disturbance in watershed
- availability of historical data
- difficulty of access

The waters sampled were primarily lakes (168 of 278; 60%) (for both studies, 362 of 504 or 72%). Streams were usually sampled when a suitable lake could not be located in a desired area, or was not accessible. In general, the lowest order stream feasible was chosen. Similarly, impoundments (defined as any water body whose level is controlled or fixed by a man-made structure) were sampled only when a natural lake was not available in the same area. This was a somewhat arbitrary distinction in some cases, since many impoundments where the dam had no provision for water level adjustment and the level had apparently been stable for several years were equivalent to "natural" lakes. Impoundments tended to be more predominant in the southern part of the study area, probably reflecting the lack of glaciation there. Impoundments which showed evidence of water level fluctuation or adjustment were avoided. Lakes sampled were classified as either "seepage" lakes with no visible inlet (n=17) or "drainage" lakes with well-defined inlets (n=151).

Geographic distribution of sampling sites over the region was as uniform as possible (Figure 1), but a few areas were inadequately represented. For example, there are few undisturbed lakes or streams in central New York.

Sampling sites were selected to represent all classes of bedrock acid neutralizing capacity and soil cation exchange capacity present in the region. Bedrock acid neutralization capacity classes were those described by Hendrey et al. (1980), and soil cation exchange capacity classes were those of McFee (1980) (Table 1).

The original maps depicting the distribution of these classes were obtained from the authors (Stephen Norton, University of Maine, Orono, and William McFee, Purdue University, Lafayette, IN, personal communications). These maps were generally of 1:500,000 scale, the same as the U. S. Geological Survey (USGS) state base map.

Waters were selected to represent the various bedrock and soil classes in approximate proportion to the area of the classes in each state. Bedrock classes were generally given preference in cases where a choice had to be made. Some waters may have been misclassified as to bedrock or soil class due to difficulty in precisely locating the water on the state base map (many small waters are not shown on these maps, and locations were transferred from 7.5 or 15 minute USGS quadrangle maps). Also, "smoothing" and other removal of complexity were performed in the creation of the bedrock and soil maps. In general, sites were selected at the highest elevations possible within chosen bedrock/soil type areas, since higher elevation, lower order waters are usually more susceptible to acidification and less likely to be affected by other forms of pollution. Headwater sites were generally low in direct human disturbance.

For each state, appropriate agencies were asked to supply existing historical water chemistry data on the chosen waters. Particular attention was given to selecting sampling sites for which there were historical data readily available; nearly half (123 of 278, 44%) of the final sites had such data (for both studies, 218 of 504 or 43%).

Finally, accessibility of the sites was considered in making a final selection. Preferred sites were at least one-half mile from the nearest vehicle access point, but not more than 2 miles from that point. Most sites had at least a marked foot trail leading from the access point to the site.

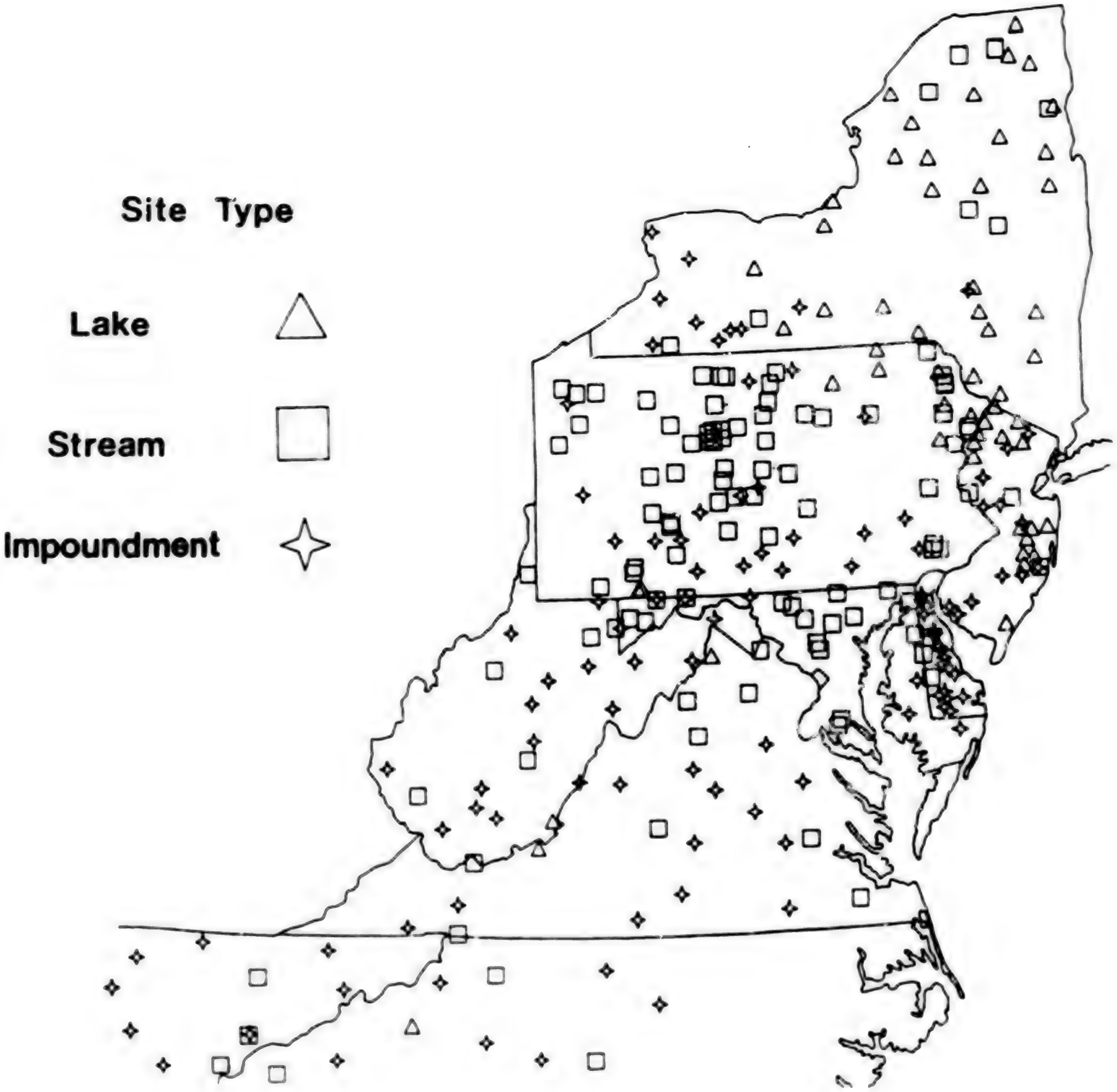

Figure 1. Map of the Middle Atlantic States showing sampling sites and type of water body for each.

Table 1. Bedrock and Soil Sensitivity (to acidification) Classes (See Hendrey et al. 1980 and McFee 1980 for further details)

Code	Class	Description
		(Rock)
1	I	No to low acid neutralizing capacity
2	II	Low to medium acid neutralizing capacity
3	III	Medium to high acid neutralizing capacity
4	IV	"Infinite" acid neutralizing capacity
5	V	Unknown but probably moderate to high acid neutralizing capacity
		(Soil)
1	S1	Sensitive soils dominate the area
2	S2	Sensitive soils are significant, but cover less than 50% of the area
3	SS1	Slightly sensitive soils dominate the area
4	SS2	Slightly sensitive soils are significant, but cover less than 50% of the area.
5	NS	The area contains mostly nonsensitive soils

Sample and Field Data Collection

Due to the large size of the study area, the sampling period extended over an entire year, July 1980 to August 1981, with most samples collected in spring and summer 1981. Some values for a particular water may thus reflect seasonal limnological conditions.

Standard field procedures were similar to those used in New England. Most water bodies selected for survey were visited by a two person survey team. All were reached by driving as close as possible with a four-wheel drive vehicle, then carrying equipment the remaining distance. The major vegetation, exposed bedrock, inflow and outflow streams, aquatic vegetation, and evidence of human activity (roads, campsites, seasonal dwellings, permanent dwellings, logging, agriculture) visible from the water and observed on the trip into and out of the area were noted. Although waters with human disturbance in the watershed were avoided, a higher proportion of slightly disturbed waters had to be included in the Middle Atlantic States than in New England due to the scarcity of completely undisturbed sites. An arbitrary code was devised to represent differing levels of disturbance; waters were assigned a code number based on a visual survey of the shoreline and watershed (Table 2). A canoe was used to reach the deepest area of lakes and ponds except in a few cases when thin ice prevented access by canoe or foot beyond shore structures (e.g., ends of docks). In such cases only near-surface samples were collected, as far from shore as feasible. Adequately frozen lakes were sampled by spudding a hole through the ice near the deepest area. "Surface" samples in these cases were collected by first gently removing the water-ice mixture from the hole and allowing it to refill, then placing the bottle about 0.5 m below the water surface. Water samples were collected in acid-washed, distilled-water-rinsed linear polyethylene bottles.

In streams, water samples were collected from mid-depth and midstream directly into the bottles. In lakes, one set of samples was collected at 0.1 m below the surface directly into the bottles and one set near the bottom (without disturbing sediment) in a plastic Van Dorn-type water sampler. Temperatures at sample depths were measured directly with a thermistor, and a Secchi disc reading was recorded in lakes. Width of streams was estimated visually at the site. Three 500 ml and two 125 ml bottles of sample were collected at each depth. All bottles were rinsed three times with the water to be sampled before filling. Bottles were filled to the brim to exclude air, thus minimizing gas exchange and consequent chemical changes. Immediately on

Table 2. Criteria Used to Estimate Relative Amount of Human Disturbance

Code	Disturbance
1	No visible disturbance: access by foot trail or aircraft only
2	Slight disturbance: access by 4-wheel drive vehicle; one or two seasonal dwellings in the watershed; evidence of logging activity but not presently active
3	Moderate disturbance: access by 2-wheel drive vehicle; more than two seasonal dwellings; evidence of active logging but not immediately adjacent to water
4	Severe disturbance: access by paved road; permanent homes around lake; agriculture in watershed; active logging adjacent to water

return to shore, 2.5 ml of 20% nitric acid was added to each 125 ml sample to preserve it for cation analysis, and all samples were placed on ice.

ANALYTICAL METHODS

Field Analyses

Initial measurements of pH and conductivity were performed in the field from 1-5 hours after collection. One 500 ml bottle from each sample depth was warmed to near 20 °C while still closed. An Orion model 399A meter equipped with an Orion model 91-62-00 glass combination electrode (specially designed for low ionic strength solutions) was used for pH determinations in the field[2]. Before each determination, the meter was standardized against pH 4 and 7 buffers. After being rinsed with distilled water and sample water, the electrode was inserted directly into the bottle and moved gently until the reading of the meter stabilized (about 5 minutes). This procedure minimized contact between sample and atmosphere, a potential source of error with poorly buffered waters. The procedure was repeated and both readings were recorded.

Conductivity of the sample was measured directly in the bottle using a Presto-Tek model DP-32 conductivity/temperature meter. Two successive readings were recorded along with the associated sample temperature; the meter had a built-in temperature compensator which standardized readings to 25 °C.

Laboratory Procedures

The remaining water samples were kept on ice, returned to the laboratory, and frozen until analyzed[3]. The acidified 125 ml bottles were given to a subcontractor (Dr. William J. Myers, Micro-Technic Systems Laboratory, Pleasant Gap, PA 16823) for analysis of aluminum, calcium, manganese, sodium, magnesium, and potassium. Total aluminum was measured by the colorimetric method of Dougan and Wilson (1974); the other elements were measured by the standard methods recommended by the U. S. Environmental Protection Agency (Kopp and McKee 1979)[4].

Samples for metal analysis were not filtered, in order to maintain compatibility with the New England study (Haines and Akielaszek 1983). Some workers believe that unfiltered samples may be preferable for aluminum analyses of poorly buffered waters low in dissolved solids (Charles Driscoll, Syracuse University, personal communication). All analyses were duplicated, using one sample from each bottle.

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[2] Haines and Akielaszek (1983) analyzed alkalinity, pH, conductivity, and color in the field, and used a plastic-body, gel-filled combination electrode on their portable pH meter.

[3] The New England samples were refrigerated, not frozen.

[4] Haines and Akielaszek (1983) analyzed sodium and potassium by air-acetylene flame atomic absorption spectrophotometry, calcium and magnesium by nitrous oxide-acetylene flame AAS, and manganese by graphite furnace AAS. They measured aluminum initially by the colorimetric method of Dougan and Wilson (1974) and later by graphite furnace AAS. The two methods gave "comparable results".

The remaining two 500 ml bottles were brought to room temperature and immediately analyzed for alkalinity, sulfate, chloride, and color. As a check on the field measurements, pH and conductivity of the thawed sample were recorded. Conductivity was re-measured using the same instrument and technique as in the field. pH was re-measured using a Corning model 125 meter equipped with the same electrode used in the field, and the same technique was employed. (As fewer problems and greater precision were noted with the lab pH measurements, they were used for the data comparisons which follow).

Alkalinity was determined by the double endpoint, potentiometric titration method as described in American Public Health Association et al. (1981). Duplicate 100 ml samples were titrated with sulfuric acid (standardized to 0.0200 *N*) to pH 4.5 and then to pH 4.2, recording the amount of acid used to reach each endpoint. This method has proven to be nearly as accurate as the Gran plot method (Stumm and Morgan 1970) and considerably faster. It is also more accurate than the fixed (single) endpoint method often used in the past by many investigators (Kramer and Tessier 1982). However, the values obtained were also used to calculate the fixed endpoint alkalinity for use in historical data comparisons.

To verify the comparability of the double endpoint method with the Gran plot method, and the analysis of frozen samples for alkalinity with unfrozen samples, we collected a set of replicated samples from 16 waters in central Pennsylvania. Nine of these waters also appeared in the project samples; the remainder were chosen to represent a broader range of trophic and chemical conditions. From each water, four samples were collected just below the surface. Two of the four were frozen for 2 weeks and thawed just before analysis (similar to the samples of the main survey); the other two were refrigerated for 2 days before analysis but not frozen. Samples were analyzed for alkalinity by both the double endpoint and Gran plot methods, and for conductivity, pH, sulfate, and color. A paired-comparison t-test (SAS Institute 1982) was used to test for differences between means of frozen and unfrozen samples for each analysis, and between double endpoint and Gran plot methods for alkalinity. Differences were standardized by means of the formula:

$$\text{difference} = \frac{\text{value before freezing} - \text{value after}}{(\text{value before} + \text{value after})\ /\ 2}$$

Replicates were treated as separate samples. Results are presented in Table 3, and show relatively small differences between the procedures under consideration.

Table 3. Comparison of Frozen and Unfrozen Sample Analyses and of Alkalinity Methods for 16 Waters (values for conductivity in µS/cm, for color in Pt-Co units and others in µeq/l)

Variable	Unfrozen mean	Unfrozen s.d.	Mean Standardized Difference (= precision)	t	p >t
Conductivity	39	5.0	0.04	1.79	0.09
Gran plot alk.	-6	39.2	0.06	1.24	0.23
Double ept. alk.	-7	38.7	0.15	1.69	0.11
Sulfate	260	18.7	0.01	0.95	0.36
Color	13	3.3	0.01	0.27	0.79
Hydrogen ion	12	11.6	0.06	0.66	0.51
Double endpoint alkalinity vs. Gran plot alkalinity (unfrozen):					
	(above)		0.07	0.90	0.38

Sulfate was determined by the barium sulfate turbidimetric method (American Public Health Association et al. 1981) using a Hach model 2100A turbidimeter. Nine standards from 0-800 µeq/l $SO_4^=$ were used to develop a calibration curve from which sample values could be determined.

Chloride was determined using the mercuric nitrate titrimetric method recommended by USEPA (Kopp and McKee 1979)[5].

Color was measured as an index of possible influence of organic acids, using the platinum-cobalt scale as represented by standard color discs in a Hellige Aqua Tester.

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[5] Haines and Akielaszek (1983) measured sulfate by the microthorin method (Fritz and Yamamura 1955) and chloride by the ferricyanide method (American Public Health Association et al. 1981).

On the advice of the author (James Kramer, McMaster University, personal communication), calcite saturation index (CSI) was calculated from the modified equation given by Kramer (1981) rather than the general equation given by Kramer (1976).

Mean amount and annual pH of precipitation at each site were determined from official state climatology maps and from the latest National Atmospheric Deposition Program (NADP) map summary, respectively.

QUALITY ASSURANCE

Analytical instruments were calibrated frequently against known standards and blanks. All analyses were performed in duplicate and statistical comparisons and evaluations were performed between the duplicates for each analysis.

As a further check on analytical accuracy and data coding errors, we calculated total ionic balance and theoretical conductivity. All ion concentrations were converted to microequivalents per liter (µeq/l), anions and cations were summed, and the sum of anions was compared to the sum of cations for each sample. Stations with large ionic concentration imbalance (± >100%) were removed from the data set before data were summarized. Theoretical conductivity was calculated by multiplying equivalent conductance of each ion from tables in Weast (1980) by the concentration of that ion for each sample and summing the results. The result was compared to measured conductivity for each sample as a check on the ionic balance; i.e., good conductivity agreement implies that all important ionic concentrations have been measured (Golterman et al. 1978).

DATA ANALYSIS

Results obtained from the above analyses were coded on a standard form used by both the New England and Middle Atlantic studies. Punched cards were produced and sent to Mr. Paul Rago at the U. S. Fish and Wildlife Service Great Lakes Fishery Laboratory in Ann Arbor, MI. Mr. Rago used the University of Michigan's MIDAS (Michigan Interactive Data Analysis System) to perform some of the more advanced statistical analyses and to produce the maps used in this report. Many of the basic correlations, regressions, and comparisons for this report were performed using a duplicate data set and the Statistical Analysis

System (SAS)[6] as installed on the IBM computer complex at The Pennsylvania State University. Further error checking was done when the data were transformed for entry into the ACID (Acidification Chemistry Information Database) system at Brookhaven National Laboratory, as a contribution to the USEPA effort to determine sensitivity to acidification of waters throughout the United States (Omernik and Powers 1982).

For lake and impoundment sites, results from the duplicate surface samples were averaged together with results from the duplicate samples taken near bottom, to produce a single value for each measurement before further statistical analysis. For streams, the duplicate mid-depth sample results were similarly averaged.

In order to avoid undetected effects of unusual chemistry or possible contamination, all stations with color 30 units or greater, with double endpoint alkalinity greater than 1000 µeq/l, with chloride greater than 500 µeq/l, or with conductivity greater than 200 µS/cm were eliminated from the data summaries which follow. These were in addition to those removed for ionic imbalance as described above. Many of the 60 stations so removed from the data set failed more than one of the above criteria. This process left 218 stations for further analysis. A list of the removed stations will be found in Appendix C.

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[6] SAS Institute, Inc., Cary, NC.

RESULTS AND DISCUSSION

QUALITY ASSURANCE

Comparison of the sums of anions and cations for each sample from the final data set yielded reasonable agreement (Figure 2). These calculations would not be expected to show perfect balance because not all the ions present were measured; anions such as nitrate in particular may have been present in significant amounts in some waters. The regression line had an intercept of 86.54 and a slope of 0.817 ($R^2 = 0.621$, $p = 0.0001$). The intercept was significantly different from zero ($p = 0.008$) and, being positive, supports the hypothesis of "missing" anions. The slope was not significantly different from 1.0 ($p = 0.0001$). The correlation was highly significant ($r = 0.788$, $p = 0.0001$).

A further check was made by calculating the theoretical conductivity of each sample based on content of each major ion, and comparing these to the conductivities actually measured. The regression line (Figure 3) had an intercept of 3.260, slightly different from zero ($p = 0.023$), and a slope of 0.605, which was significantly different from 1.0 ($p = 0.0001$) ($R^2 = 0.847$, $p = 0.0001$). The correlation, however, was highly significant ($r = 0.920$, $p = 0.0001$). Figure 3 also supports the hypothesis that not all ions present were measured, since in nearly every case the measured conductivity was greater than the theoretical based on those ions actually measured.

We also performed an analysis of correlation and percent difference between the duplicate analyses for each sample. The results are presented in Table 4.

These comparisons indicate that the data set is free of major analytical or transcription errors.

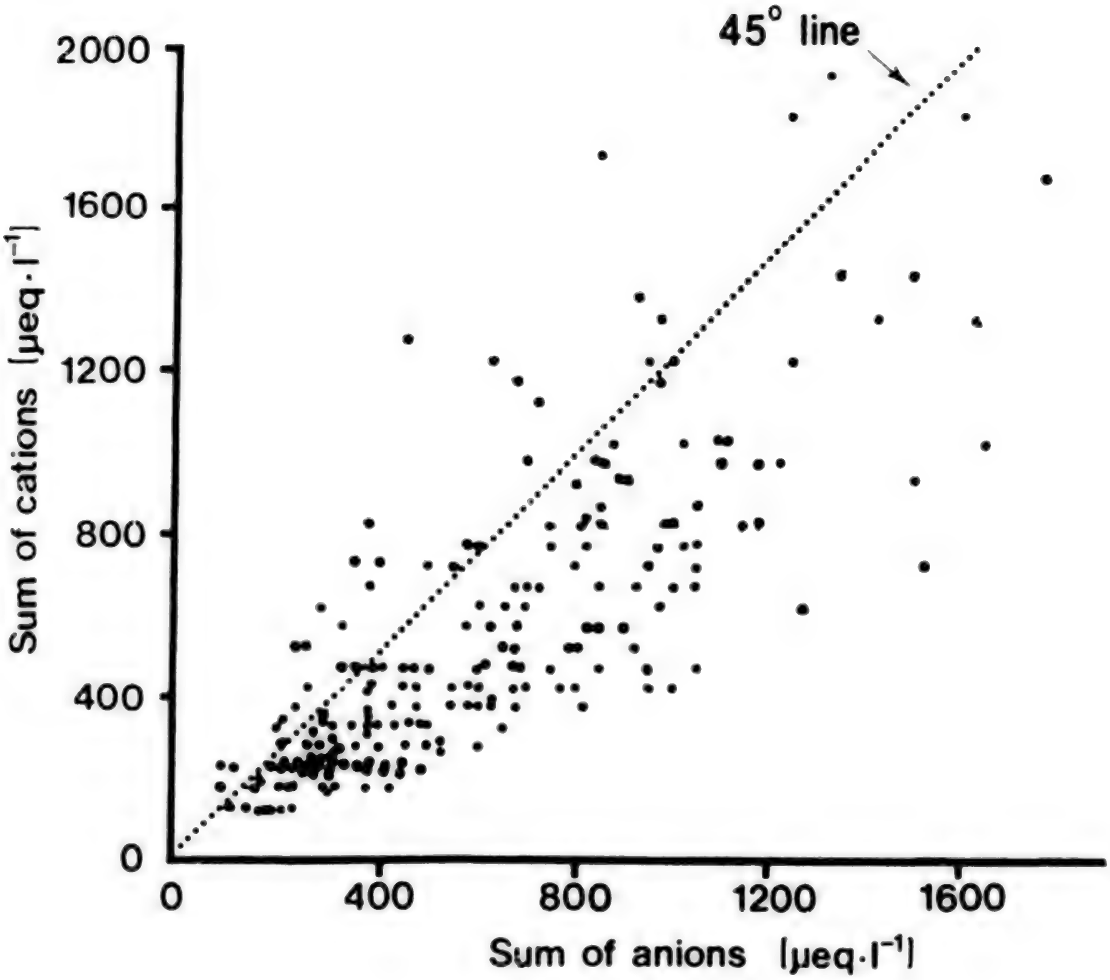

Figure 2. Sum of cations versus sum of anions for 211 sites, all samples averaged for each site. Least squares regression equation: sum of cations = 0.817 sum of anions + 86.54 ($R^2 = 0.621$, $p = 0.0001$). Correlation coefficient (r) = 0.788, $p = 0.001$. (seven sites omitted due to missing values).

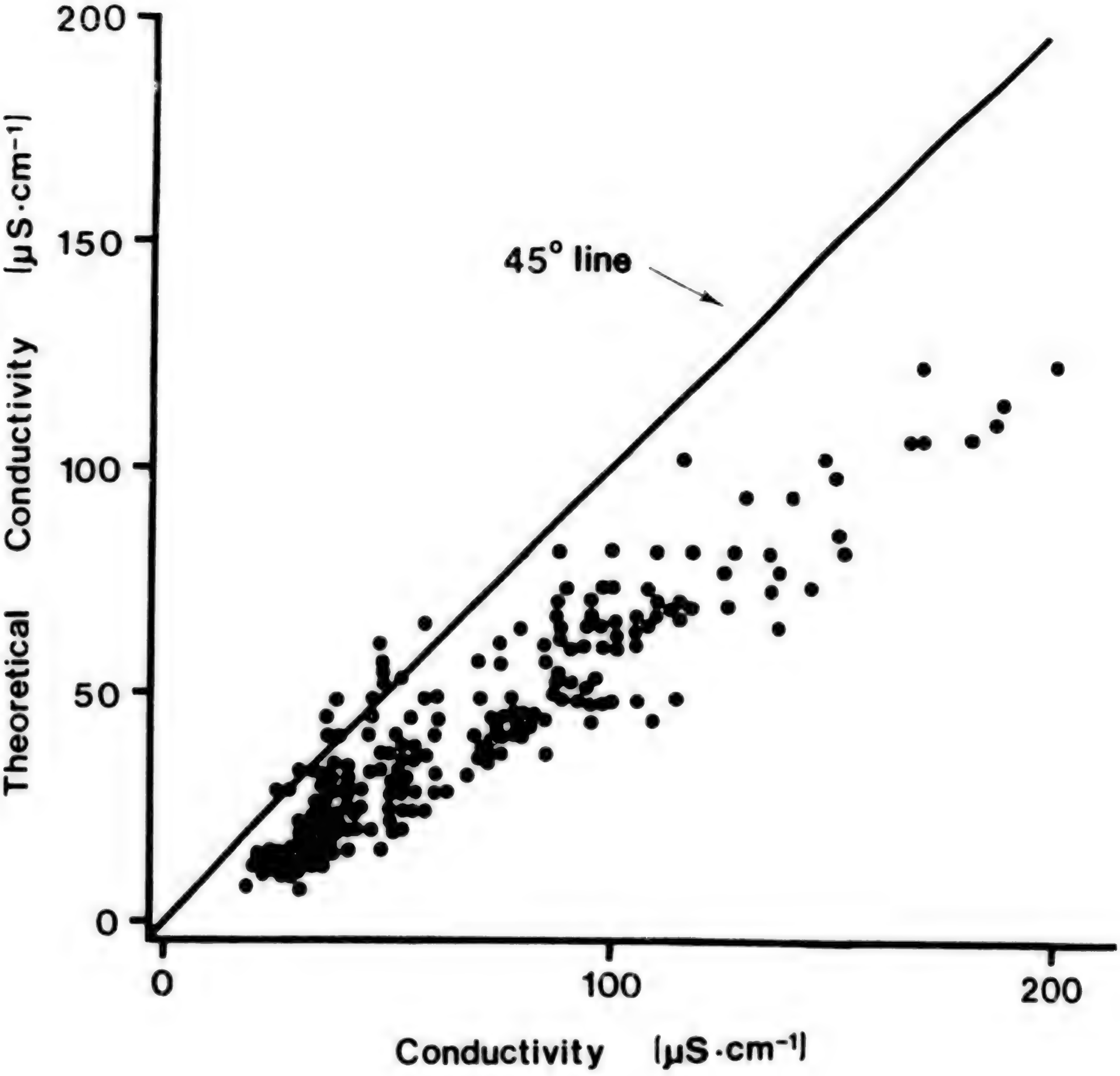

Figure 3: Theoretical versus measured conductivity for 211 sites, all samples averaged for each site. Least squares regression equation: theoretical conductivity = 3.260 + 0.605 measured conductivity (R^2 = 0.847, p = 0.0001). Correlation coefficient (r) =0.920, p = 0.0001. (Seven sites omitted due to missing values).

Table 4. Comparison of Duplicate Chemical Analyses for all Samples

	Sample 1 *vs* Sample 2			
Ion or Measurement	Number of pairs	r (p = 0.0001)	mean standardized % difference (= precision)	std. dev.
Hydrogen ion	325	0.974	1.4	57.6
Alkalinity	318	0.967	3.2	65.1
Conductivity	322	0.974	0.3	12.9
Aluminum	333	0.845	17.8	55.0
Calcium	333	0.999	1.2	2.8
Chloride	317	0.834	1.4	48.5
Potassium	333	0.999	1.4	2.7
Magnesium	333	0.999	1.2	2.6
Manganese	333	0.999	42.9	81.2
Sodium	333	0.999	1.6	19.2
Sulfate	324	0.803	0.1	24.2
Color	324	0.948	4.6	59.5

SITE DISTRIBUTION

We sampled 278 lakes and streams in the nine states. (Figure 1). The distribution of sites among states (Table 5) was roughly proportional to the areas of the states, but additional stations were included where convenient (e.g., Delaware) or where waters were being sampled for other projects (e.g., Pennsylvania). Lakes and impoundments comprised 61% of the sites, and streams comprised 39%. These percentages are somewhat different from those of the New England study (85% and 15% respectively) due to the scarcity of suitable lakes in most of Pennsylvania and some other areas. Stream order ranged from 1 to 4 (N: 1=26, 2=44, 3=26, 4=14). Site elevations ranged from 2 m (MSL) to 1181 m, with a mean of 330 m.

The distribution of sites by bedrock geology and soil classes present in each state is shown in Table 6. The distributions are not exactly proportional to each other or to the total area of each type in each state because suitable waters

Table 5. Number and Classification of Lakes and Streams Sampled in Each State

State	Streams	Lakes		Total (%)	Area of State as % of total 9-state area	No. (%) removed from chemical analysis summaries
		Natural	Impoundment			
Delaware	2	0	19	21(7.6)	1.0	2(10)
Maryland	17	0	7	24(8.6)	5.2	9(38)
New Jersey	3	16	12	31(11.2)	3.9	8(26)
New York	8	28	10	46(16.5)	24.4	11(24)
North Carolina	3	1	6	10(3.6)	6.5a	1(10)
Pennsylvania	59	9	20	88(31.7)	22.3	14(16)
Tennessee	3	0	8	11(3.9)	5.2a	3(27)
Virginia	9	2	13	24(8.6)	19.6	4(17)
West Virginia	6	1	16	23(8.3)	11.9	8(35)
Total	110	57	111	278(100)	100.0	60(22)

[a] Areas for Tennessee and North Carolina were divided by four since only the Appalachian parts of those states were sampled.

Table 6. Distribution of Sampling Sites Among States by Bedrock and Soil Types

		Number and (%) of Stations on Bedrock Type				Numbers and (%) of Stations on Soil Type			
State	Number of Stations	I	II	III	VI	NS	SS1	SS2	S2
Delaware	21	0	4 (19)	17 (81)	0	1 (5)	6 (28)	14 (67)	0
Maryland	24	0	15 (62)	5 (21)	4 (17)	8 (33)	10 (42)	5 (21)	1 (4)
New Jersey	31	5 (16)	24 (76)	0	2 (8)	12 (39)	9 (29)	10 (32)	0
New York	46	7 (15)	32 (70)	2 (4)	5 (11)	31 (68)	11 (24)	2 (4)	2 (4)
North Carolina	10	1 (10)	7 (70)	2 (20)	0	1 (10)	8 (80)	1 (10)	0
Pennsylvania	88	0	51 (58)	25 (28)	12 (14)	46 (52)	21 (24)	15 (17)	6 (7)
Tennessee	11	0	3 (27)	0	8 (73)	0	8 (73)	3 (27)	0
Virginia	24	4 (17)	9 (37)	5 (21)	6 (25)	0	21 (88)	3 (12)	0
West Virginia	23	0	10 (44)	12 (52)	1 (4)	6 (26)	16 (70)	1 (4)	0
TOTAL	278	17 (6)	155 (56)	68 (24)	38 (14)	105 (38)	110 (40)	54 (19)	19 (3)

were seldom ideally located with respect to either factor. Sites were chosen primarily in proportion to bedrock and secondarily in proportion to soils. Most sites were on nonsensitive or slightly sensitive soils and/or on bedrock of low to medium acid neutralizing capacity.

Distribution of sites by bedrock class is shown in Figure 4. As might be expected, sites in mountainous areas (generally in the northwestern half of the study area) are usually on bedrock classes I and II (most sensitive). On the other hand, there are frequent occurrences of sites on less-sensitive bedrock in mountainous areas. This emphasizes the point that generalized maps showing large sensitive (or nonsensitive) areas, e.g. Likens et al. (1979) and Comptroller General (1981), can be misleading.

Distribution of sites by soil class is shown in Figure 5. No suitable waters on soil type S1 ("sensitive soils dominate the area") were available.

CHEMICAL FACTORS

Organic Acids and Color

We measured color as an index of possible presence of organic acids or other contaminants. Only eight of our 278 waters had average color values of 30 or greater, and these were omitted from our data analysis. (Another 52 were omitted for other reasons.) For the remaining 218 stations, the mean color value was 6.04 units, and only six were above 20 units.

Haines and Akielaszek (1983) derived the relationship TOC (mg/l) = 1.32 + 0.0613 color (Pt-Co units) from analysis of total organic carbon (TOC) on a 31-sample subset of their data. We used this equation for our samples and found no significant relationship between $\log_{10}$TOC ($R^2 = 0.00003$, $p = 0.980$) or color ($R^2 = 0.0001$, $p = 0.866$) and pH. Similarly, there was no significant relationship between log TOC ($R^2 = 0.0052$, $p = 0.276$) or color ($R^2 = 0.0028$, $p = 0.422$) and alkalinity.

We also examined the relationship between aluminum and organic carbon, since it has been reported that aluminum forms strong organic complexes which could affect aluminum concentrations (Driscoll et al. 1980). The regression of aluminum on TOC for our samples was not significant ($R^2 = 0.0103$,

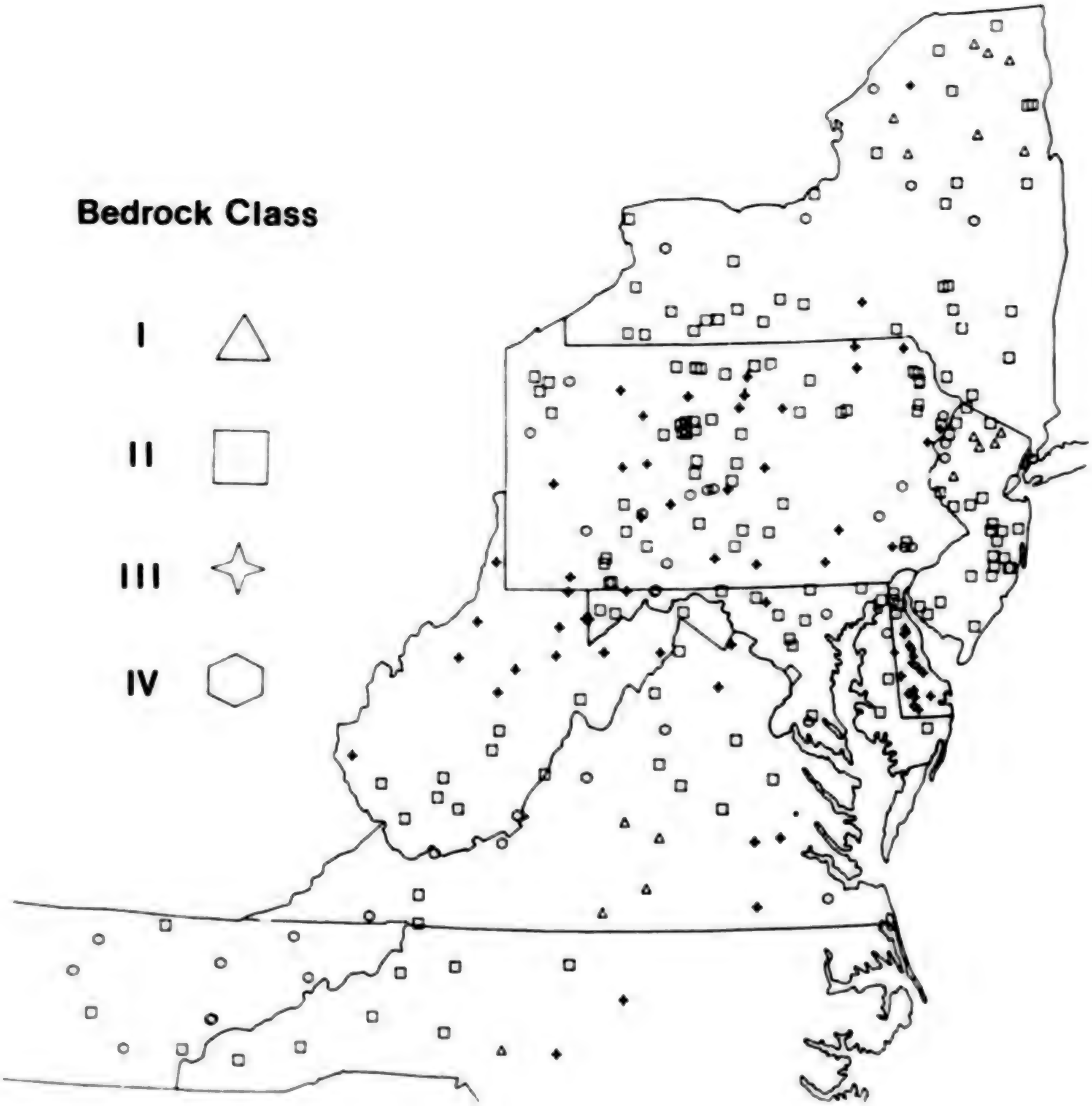

Figure 4. Map showing distribution of sampling sites by bedrock classification (see Table 1 for description of classes).

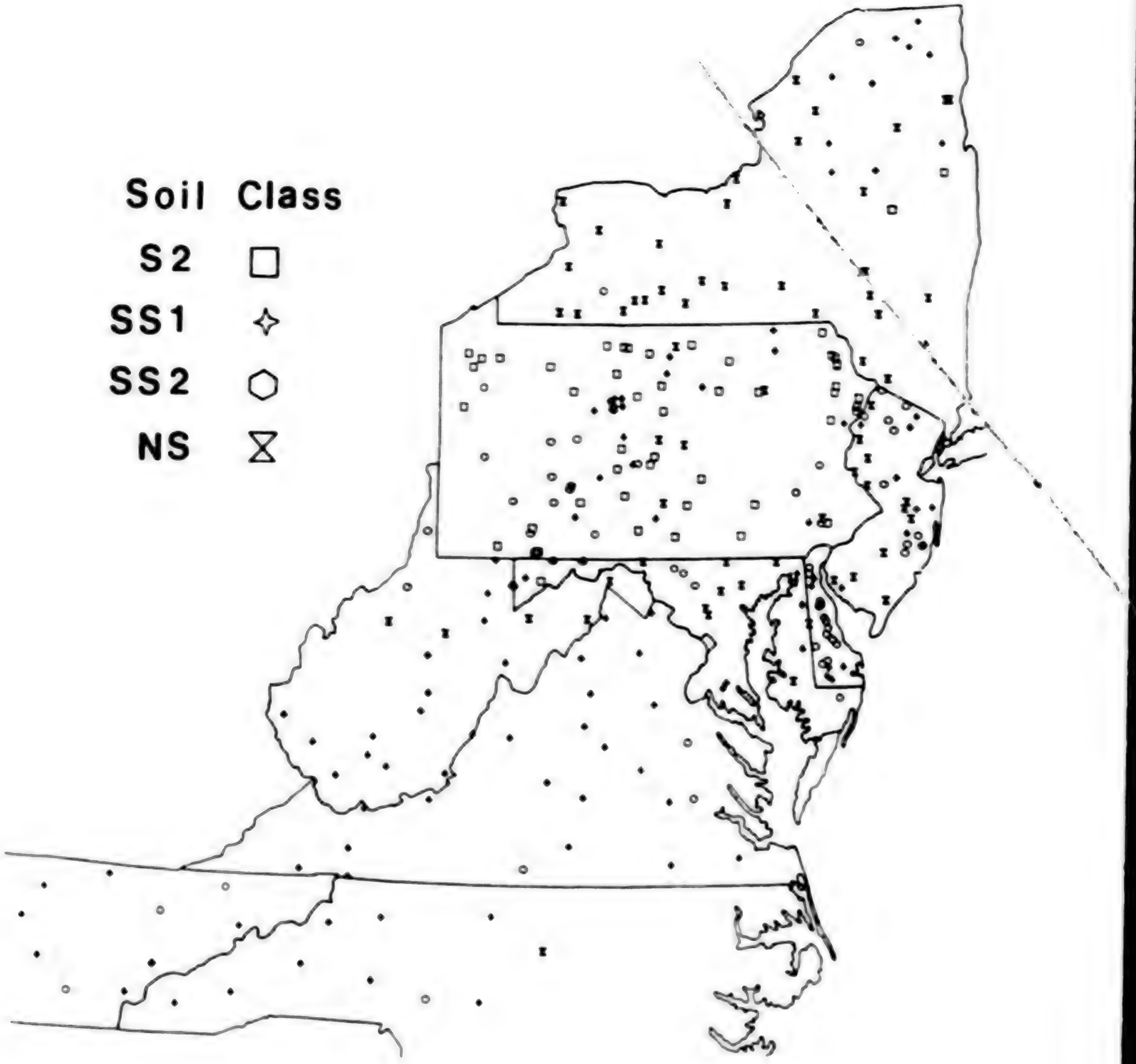

Figure 5. Map showing distribution of sampling sites by soil classification (see Table 1 for description of classes).

p = 0.126), nor was there a relationship between aluminum and color itself (R^2 = 0.0078, p = 0.184).

pH and Alkalinity

The distribution of waters by pH (surface values) is shown in Figure 6. Only in five of the nine states did we sample waters whose pH's were less than 5.5 at the time of sampling. Nearly half (13 of 31) of the waters with pH less than 5.5 were in the sandy, low-lying areas of New Jersey. Seven states had some waters with pH between 5.5 and 6.5. In all but one state, the largest group of waters was in the range pH 6.5-7.5. The exception was New Jersey, in which slightly more were below 5.5. Table 7 is a summary of the distribution of pH values by state.

The distribution of alkalinity values (Figure 7) was similar to that of pH, although a somewhat larger portion fell in the more sensitive (lower alkalinity) class. Only Delaware had no waters with alkalinity below 100 µeq/l. There were more waters which appeared to be sensitive, or already becoming acidified, on the basis of alkalinity than on the basis of pH. This is not surprising considering the temporal variation common in pH readings. Table 8 is a summary of alkalinity values by state.

pH was correlated strongly (r >0.3) with alkalinity, conductivity and (negative) calcite saturation index, and weakly (r <0.3) with calcium, magnesium, and disturbance. Alkalinity was strongly correlated with calcium, pH, conductivity, and magnesium, and weakly with sulfate, chloride, disturbance, rain pH, and (negative) elevation. Neither pH nor alkalinity was correlated with aluminum, manganese, color, total organic carbon (as predicted from color), elevation, or size of waters.

Haines and Akielaszek (1983) compared a number of regional surface water chemistry studies with respect to pH and alkalinity. Tables 9 and 10 are summaries of those studies compared with the present study; they suggest that waters with low pH and alkalinity are more likely to be found in areas receiving pronounced acidic precipitation.

The overall pH of precipitation averaged 4.3 over our study area, but many locations within it averaged near 4.0. Our study waters appear generally to be less sensitive than most sites in other surveys of areas receiving acidic deposition, but are clearly more sensitive or, in some cases, more acidified, than

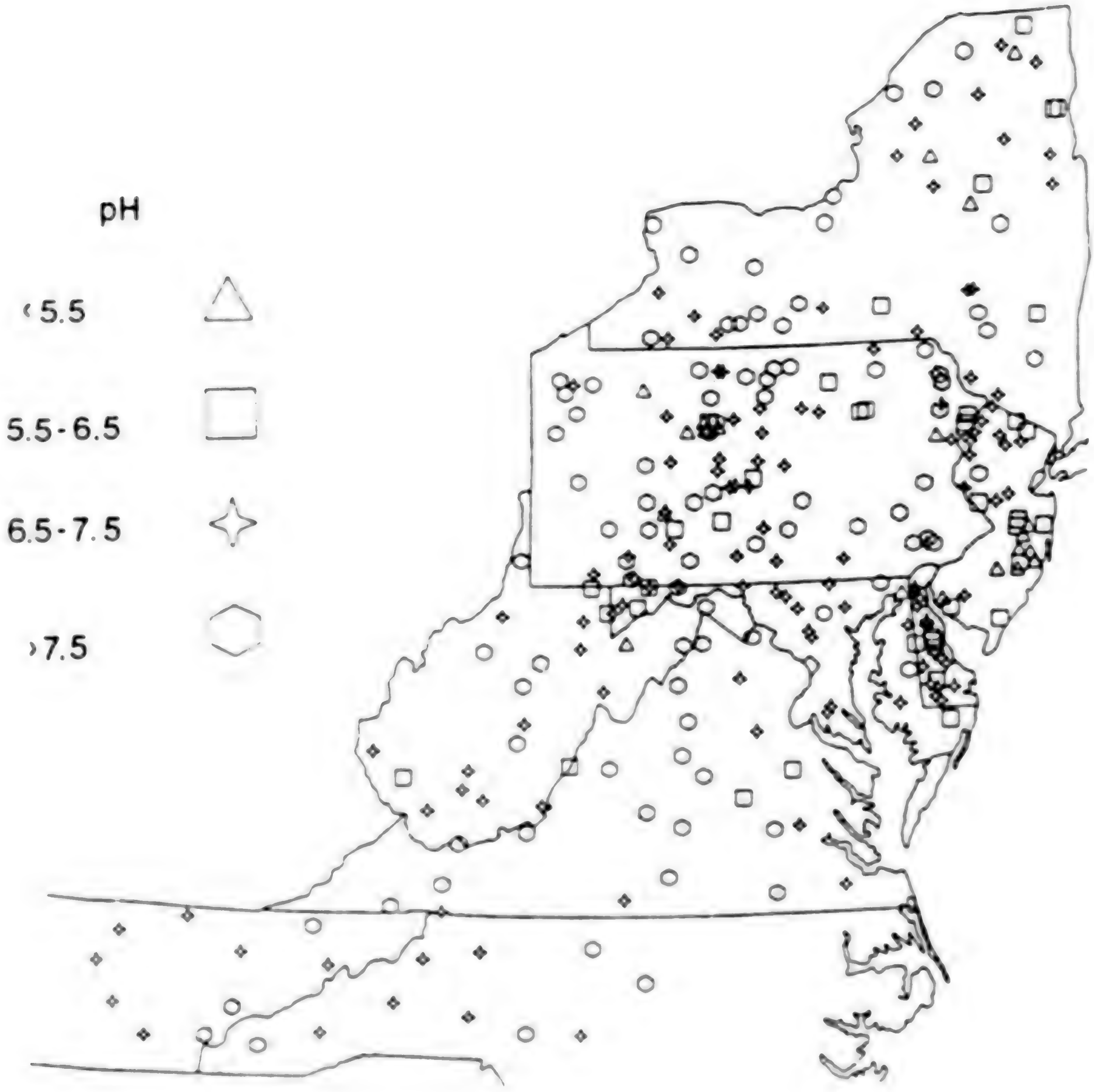

Figure 6. Map showing distribution of sampling sites by water pH. Data are for surface samples only and are means of duplicate analyses.

Table 7. Distribution of Average pH Values for Sampled Waters by State

State	n	Percent in pH Range			
		<5.5 (n=20)	5.5-6.5 (n=33)	6.5-7.5 (n=112)	>7.5 (n=53)
Delaware	19	0	11	89	0
Maryland	15	7	20	60	13
New Jersey	23	40	30	30	0
New York	35	3	11	51	35
North Carolina	9	0	0	67	33
Pennsylvania	74	11	15	42	32
Tennessee	8	0	0	75	25
Virginia	20	0	10	50	40
West Virginia	15	7	27	53	13
All waters	218	9	15	51	25

Table 8. Distribution of Average Alkalinity (μeq/l) Values for Sampled Waters by State

State	n	Percent in Alkalinity Range			
		<100 (n=68)	100-200 (n=36)	200-400 (n=61)	>400 (n=53)
Delaware	19	0	10	74	16
Maryland	15	13	13	40	34
New Jersey	23	57	17	9	17
New York	35	26	20	23	31
North Carolina	9	11	11	45	33
Pennsylvania	74	43	16	15	26
Tennessee	8	38	0	25	37
Virginia	20	10	20	50	20
West Virginia	15	40	27	27	6
All waters	218	31	17	28	24

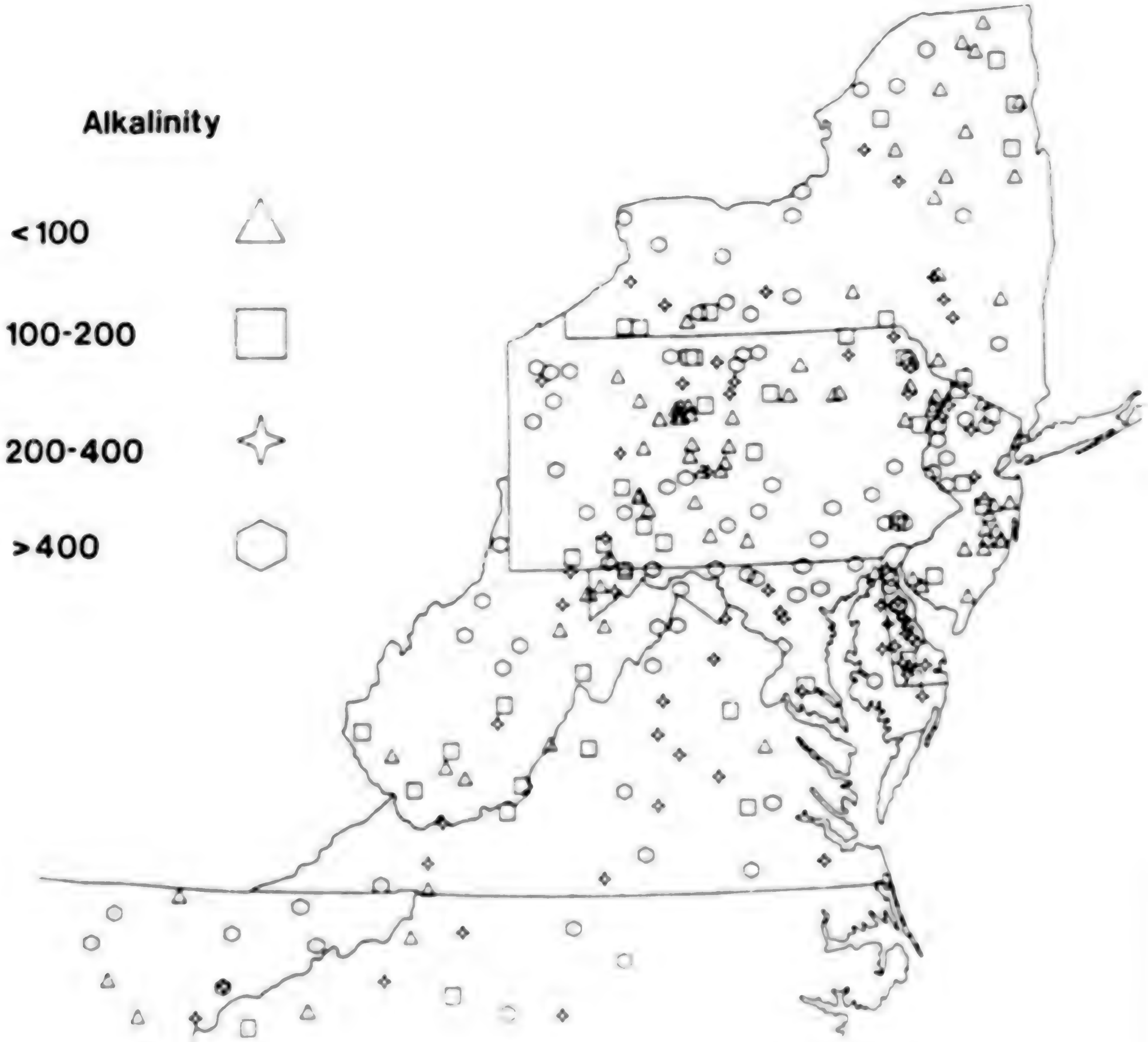

Figure 7. Map showing distribution of sampling sites by alkalinity (μeq/l). Data are for surface samples only and are means of duplicate analyses.

Table 9. pH of Surface Waters Reported by Regional Surveys (Modified from Haines and Akielaszek 1983).

Location	Number	Percent in pH Range			Reference
		<5	5-6	>6	
Areas Where Precipitation Averages ≤ pH 4.6					
Middle Atlantic	218	4	4	92	This study
New England	226	8	21	71	Haines & Akielaszek 1983
West Sweden	314	36	21	43	Almer et al. 1974
West Sweden	15	27	47	27	Dickson 1975
South Sweden	51	2	20	78	Malmer 1975
South Norway	155	18	38	44	Wright et al. 1977
South Norway	719	64	33	3	Wright and Snekvik 1978
Denmark	14	29	57	14	Rebsdorf 1980
Scotland	72	26	36	38	Wright et al. 1980
Nova Scotia	21	52	24	24	Watt et al. 1979
Quebec	25	12	40	48	Jones et al. 1980
Central Ontario	26	8	58	34	Scheider et al. 1979
LaCloche Mts.	152	28	34	38	Beamish and Harvey 1972
Sudbury, Ont.	150	13	15	72	Conroy et al. 1976
Adirondack Mts.	849	25	30	45	Pfeiffer and Festa 1980
Areas Where Precipitation Averages > pH 4.6					
North Norway	77	0	13	87	Wright and Gjessing 1976
N. W. Wisconsin	265	0	6	94	Lillie and Mason 1980
North Minnesota	85	0	0	100	Glass and Loucks 1980

Table 10. Alkalinity of Surface Waters Reported by Regional Surveys. (Alkalinity Values are in μeq/l) (Modified from Haines and Akielaszek 1983).

Location	Number	Percent in alkalinity range				Reference
		<20	20-100	101-200	>200	
Areas Where Precipitation Averages ≤ pH 4.6						
Middle Atlantic	218	15	17	17	51	This study
New England	226	23	18	12	47	Haines and Akielaszek (1983)
South Norway	62	3	11	2	84	Wright et al. 1977
Denmark	14	86	14	0	0	Rebsdorf 1980
Nova Scotia	21	71	24	0	5	Watt et al. 1979
Central Ontario	26	12	73	15	0	Scheider et al. 1979
Ontario	600	--	16[a]	32[b]	52	Zimmerman and Harvey 1979
La Cloche Mountains	4	100	0	0	0	Beamish 1976
Adirondack Mountains	692	41	25	18	16	Pfeiffer and Festa 1980
Areas Where Precipitation Averages > pH 4.6						
Northwest Wisconsin	265	--	15[c]	17	68	Lillie and Mason 1980
North Minnesota	85	0	22	26	52	Glass and Loucks 1980

[a] <50 μeq/l
[b] 51-200 μeq/l
[c] <100 μeq/l

those receiving less acidic deposition. It is clear that many waters sensitive to acidification exist within the Middle Atlantic States.

A map of acid deposition (Figure 8) shows relatively uniform loadings over the study area except for higher loadings near the common border of New York, New Jersey, and Pennsylvania. This border area, however, contained many waters with higher pH (Figure 6) and alkalinity (Figure 7) and low calcite saturation index (Figure 9). These waters appear to be relatively resistant to acidification despite being located on relatively sensitive bedrock types (Figure 2), perhaps because of nonsensitive and slightly sensitive soils present in their watersheds (Appendix A) as noted by Gmur (Nicholas Gmur, Brookhaven National Laboratory, personal communication).

Calcite Saturation Index

The calcite saturation index (CSI) has been proposed as an index of vulnerability to acidification by Conroy et al. (1974) and Kramer (1976). It is calculated as:

$$\mathrm{CSI} = p(\mathrm{Ca}^{++}) + p(\text{alkalinity}) - p(\mathrm{H}^{+}) + pK$$

where:

$p(X) = \log_{10}(X)$

$p(K) = 1.98$ at 25 °C

Ca^{++} = moles/l

alkalinity and H^{+} = equivalents/l

Generally, higher values of CSI reflect lower acid neutralizing capacity. We grouped our samples into categories of CSI less than 1, between 1 and 3, and greater than 3 (modified from Kramer 1976 and Glass and Loucks 1980).

The distribution of stations by CSI is shown in Figure 9. It can be readily seen by comparison with Figures 7 and 8 that the areas where most waters had CSI less than 1 were in general those with the highest pH and/or alkalinity waters. Values of CSI less than 1 represent waters that are saturated or nearly saturated with respect to calcite and would not be susceptible to acidification from acidic precipitation. Values of 1-3 represent waters potentially susceptible, and values greater than 3 represent definite susceptibility. Of the waters in our study, 11% were not susceptible, 57% were potentially susceptible, and 32% were susceptible, on the basis of CSI. CSI was correlated (r >0.3) negatively with pH, alkalinity, calcium, conductivity, and magnesium, as expected. There were weaker correlations with

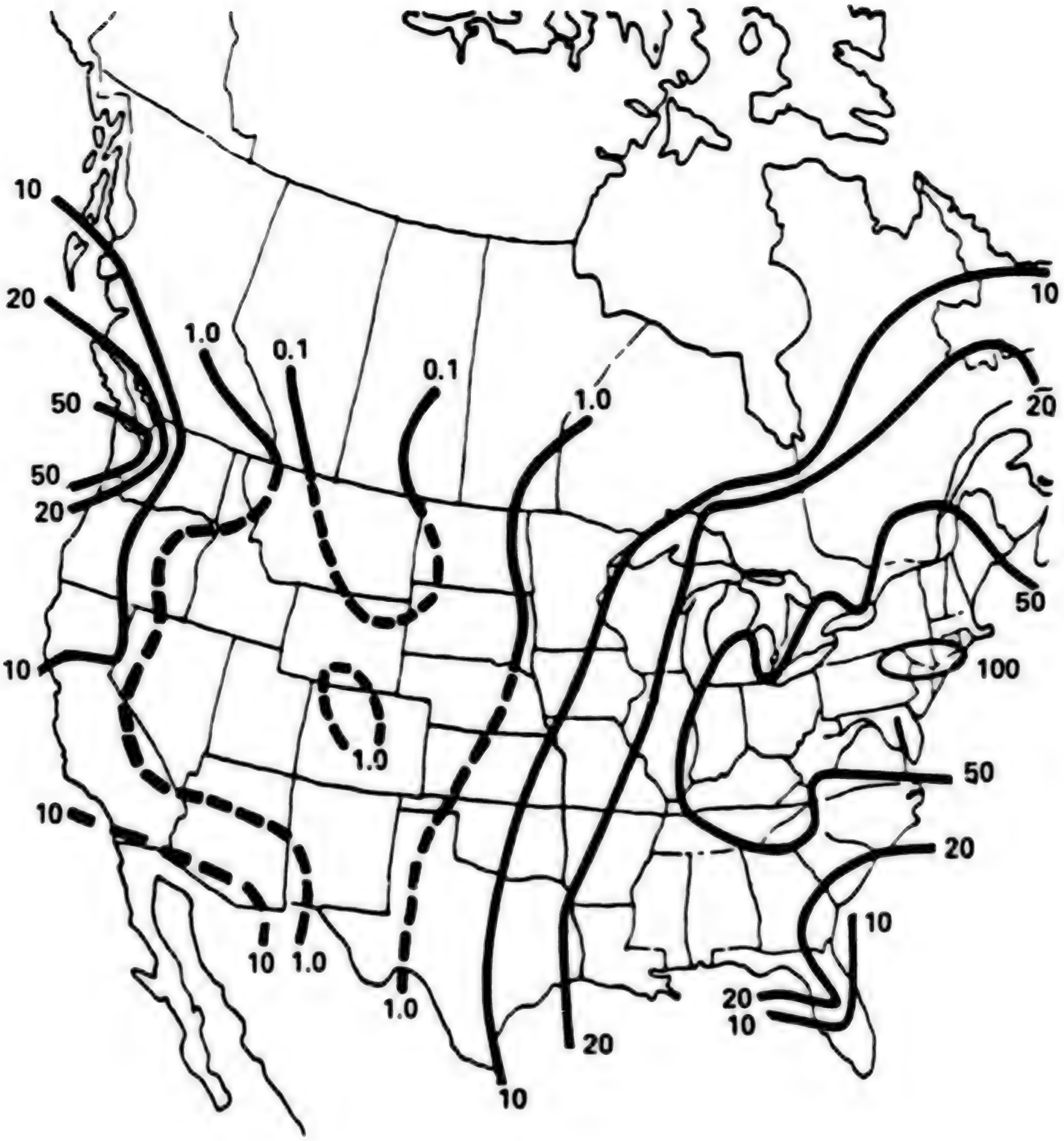

Figure 8. Map showing mean annual acid deposition from precipitation for period 1976-1979. (Units are $mg/m^2/yr$ hydrogen ion). From February 1981 Interim Reports by work groups under U.S. - Canada Memorandum of Intent on Transboundary Air Pollution. Reprinted in Comptroller General (1981).

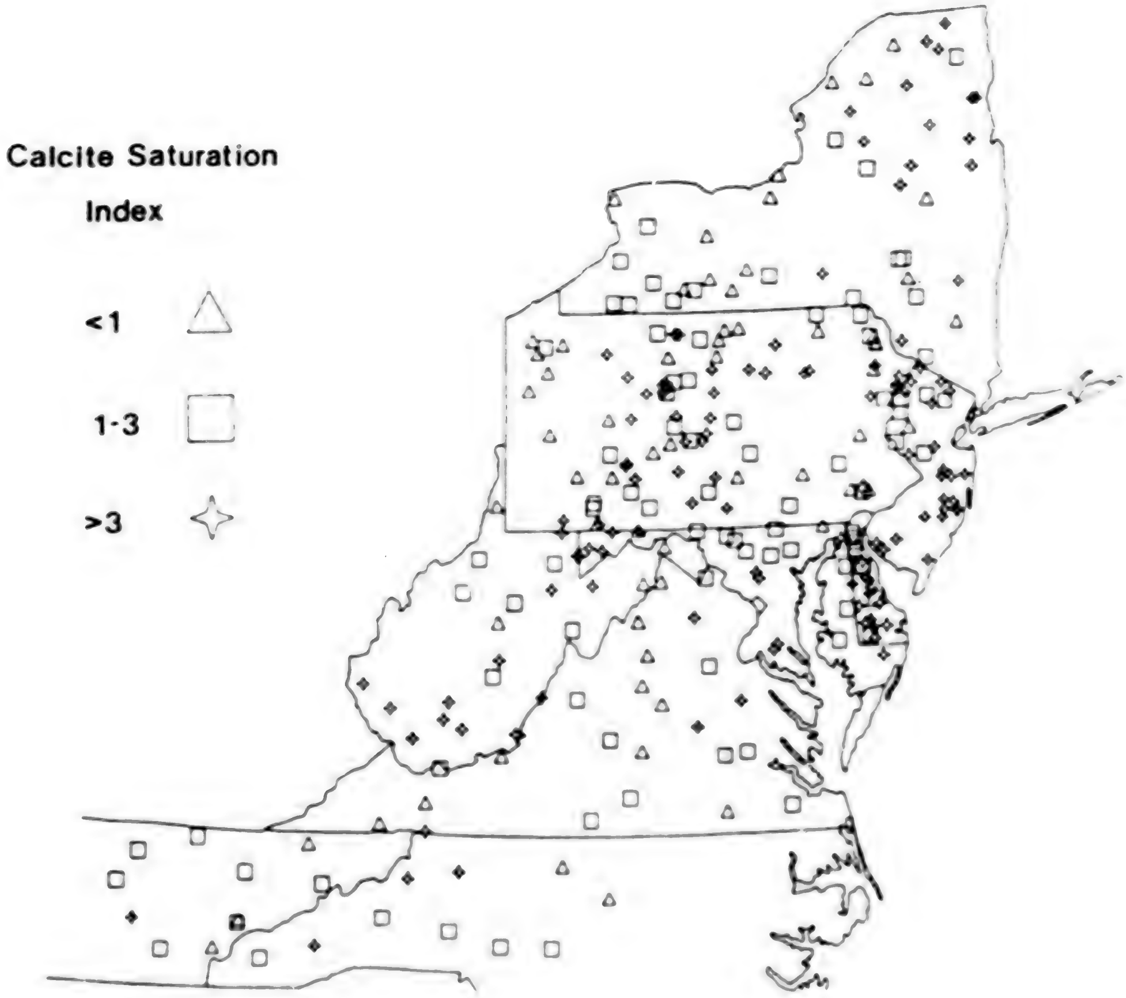

Figure 9. Map showing distribution of sampling sites by calcite saturation index. Data are for surface samples only and are means of duplicate analyses. Higher values of CSI indicate lower acid neutralizing capacity.

elevation (positive), disturbance, sulfate, and amount of annual precipitation (all negative). Table 11 is a summary of CSI distribution by state.

Table 11. Percent Distribution of Calcite Saturation Index by State

State	n	Calcite Saturation Index		
		<1	1-3	>3
Delaware	19	0	89	11
Maryland	15	13	67	20
New Jersey	23	4	65	31
New York	35	23	49	28
North Carolina	9	12	44	44
Pennsylvania	74	12	54	34
Tennessee	8	0	75	25
Virginia	20	5	60	35
West Virginia	15	7	27	66
Whole Study	218	11	57	32

Haines and Akielaszek (1983) determined that 59% of the waters they surveyed in New England could be classified as susceptible on the basis of CSI. They reviewed several other studies (Kramer 1981, Glass and Loucks 1980, and Zimmerman and Harvey 1979) and concluded that CSI does not provide a predictive ability any better than that of pH and alkalinity measurements alone. In our study, 49% of the waters sampled were susceptible on the basis of alkalinity less than 200 µeq/l, and 32% were susceptible on the basis of CSI greater than 3. Furthermore, CSI showed a strong negative correlation with alkalinity ($r = -0.657$, $p = 0.0001$) (Figure 10). Therefore, we see no advantage in the use of CSI as a predictor of vulnerability of Middle Atlantic States waters over the use of alkalinity, except that it does relate alkalinity and vulnerability to calcium concentration.

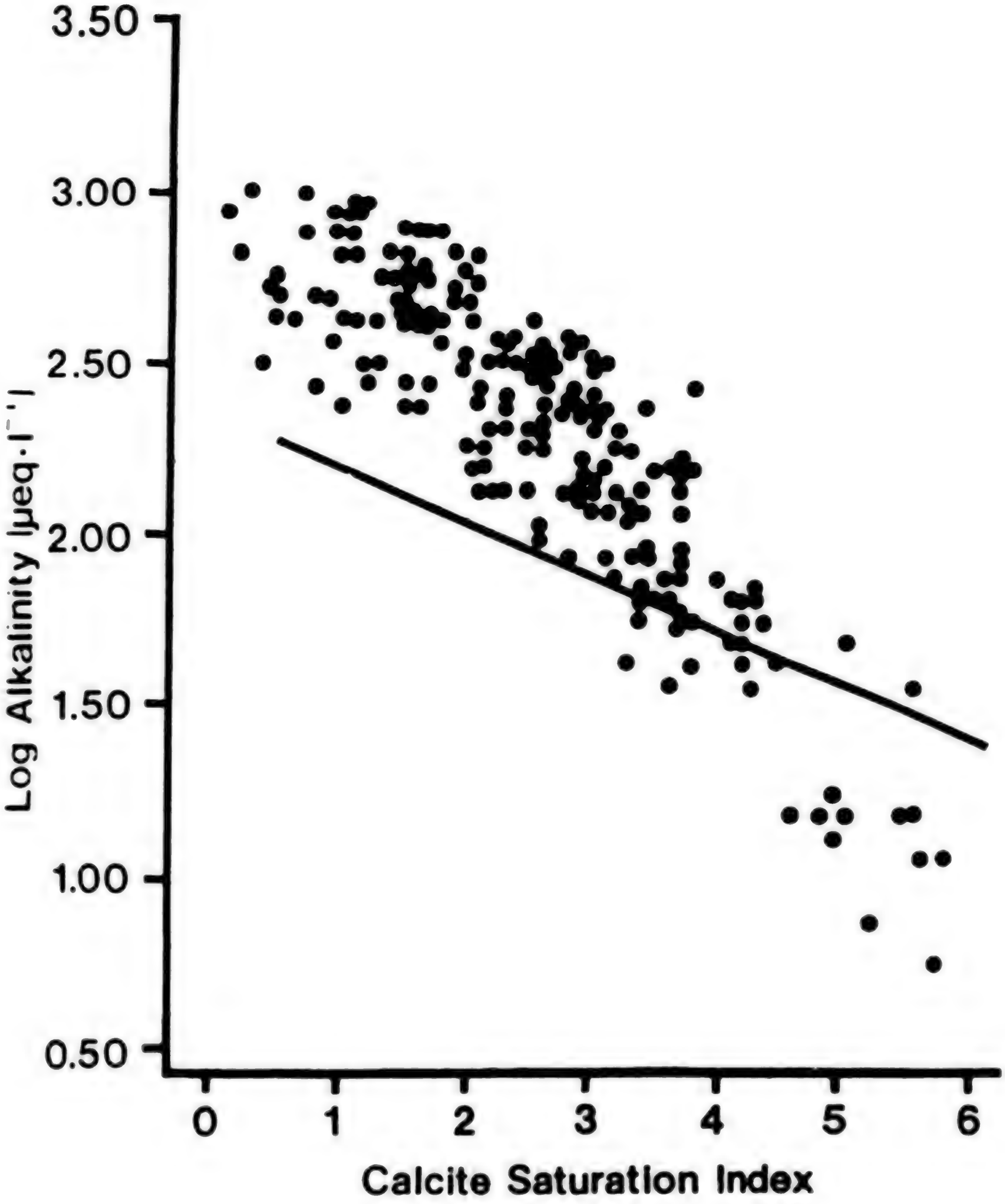

Figure [illegible]. Relation of log of alkalinity to calcite saturation index for 218 sampled waters (one point hidden). Data are means of duplicate analyses and means of surface and bottom samples where taken. Least squares regression equation: log alkalinity = 2.367 - 0.154 CSI (R^2 = 0.038, p = 0.004).

Conductivity and Ionic Composition

Conductivity (= specific conductance) is an easily measured, widely used parameter which is directly related to the total ionic content of a water sample. It thus has potential as a simple index of sensitivity to acidification. However, in some cases, factors such as proximity to the seacoast (a source of airborne salts) and differences in ion activities may limit its usefulness as a predictive device.

The 218 waters included in this analysis had a range of conductivity from 17 to 199 µS/cm, and averaged 70. Conductivity was positively correlated ($r > 0.03$) with alkalinity, calcium, chloride, magnesium, sodium, and sulfate, and negatively correlated with elevation, pH, CSI, Secchi disc transparency, and disturbance. The relationship between conductivity and alkalinity (Figure 11) was statistically significant ($R^2 = 0.502$, $p = 0.0001$) but a few waters with relatively high conductivity were low in alkalinity. This may be due to conductivity of elevated hydrogen ion (Weast 1980) or unusual mineralogy. There was no correlation between conductivity and distance from the seacoast. Table 12 is a comparison of the relative concentration of major ions in our waters with those of the New England study (Haines and Akielaszek 1983) and with world averages.

Table 12. Percent Relative Composition of Major Ions in Sampled Waters Compared with New England (Haines and Akielaszek 1983) and World Averages (three world averages from other authors combined from Henriksen 1980)

Ions	World average	New England			This study		
		pH<5	pH5-6	pH>6	pH<5	pH5-6	pH>6
Cations							
Ca+Mg	88.2	79.5	79.9	91.0	62.8	75.6	80.9
Na+K	11.8	20.5	20.1	9.0	37.2	24.4	19.1
Anions							
HCO_3	82.7	0	15.4	74.8	0	12.5	56.9
SO_4	17.3	100	84.6	25.2	100	87.5	43.1

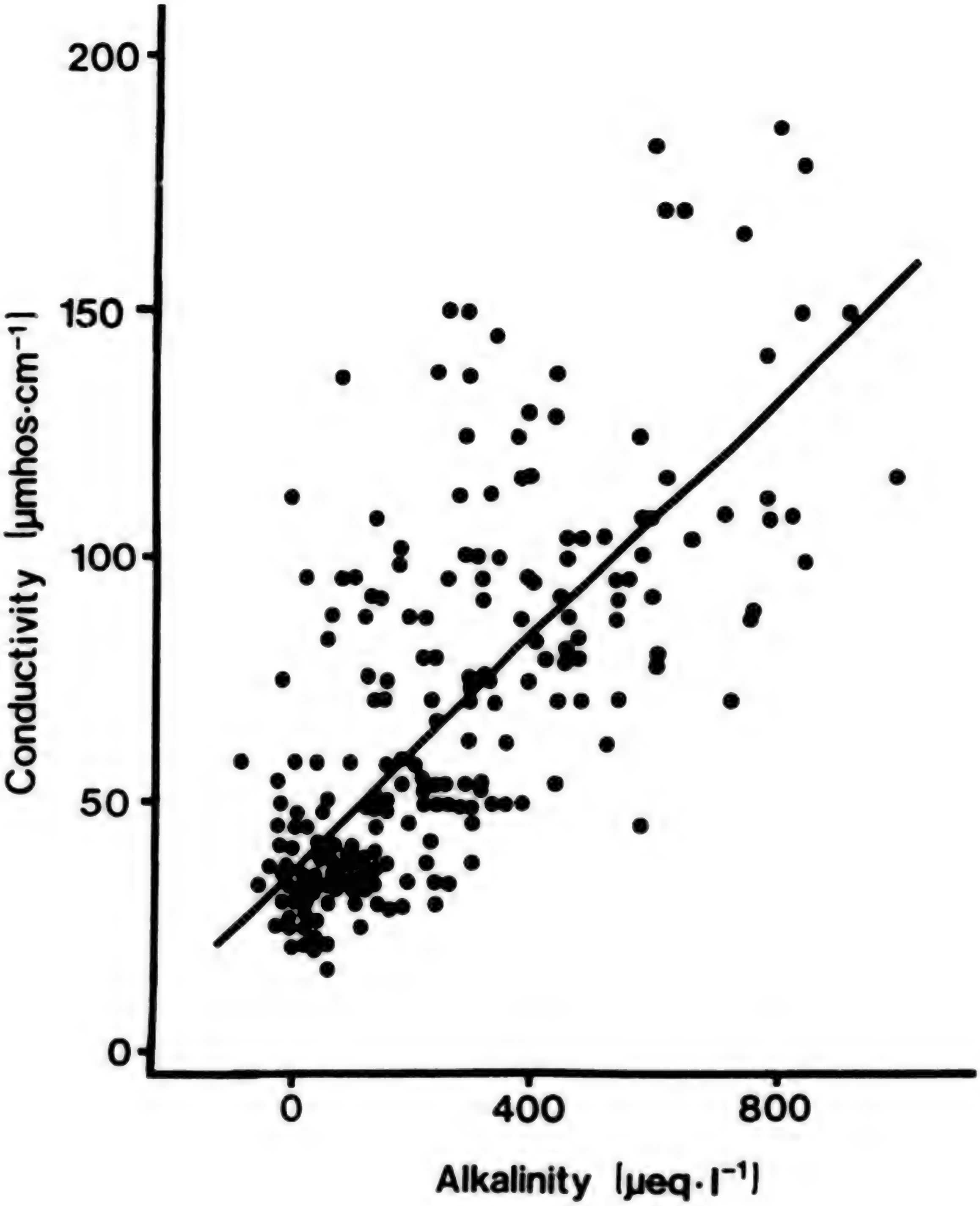

Figure 11. Relation of alkalinity to conductivity for 218 sampled waters (2 points hidden). Data are means of duplicate analyses and of all depths sampled. Least squares regression equation: conductivity = 0.115 alkalinity + 39.225 (R^2 = 0.502, p = 0. 0001).

As noted in the New England investigation, ionic composition of the surface waters varied markedly with pH (Figure 12). However, all pH classes of our waters had higher mean ionic content than the corresponding New England class, and the differences between total means were not as great. Total ionic content was highest at high pH and declined at successively lower pH.

Other similarities between our data and that from New England are evident: bicarbonate disappeared below pH 5, as expected, and sulfate remained at approximately the same concentration while making up a greater proportion of total anions as pH decreased. The cations calcium and magnesium declined markedly with pH, but sodium and potassium showed no such trend. This is probably related to the sources of these ions; calcium and magnesium are assumed to originate primarily from the watershed and are related to acid neutralizing capacity, but sodium and potassium are assumed to originate primarily from other sources and are not involved with buffering reactions. Aluminum was approximately equal in the pH >6 and 5-6 classes, but more than doubled below pH 5. This is consistent with the fact that aluminum is more soluble at low pH and thus is frequently mobilized from watersheds under acidic conditions.

Chloride

Chloride was measured as a potential indicator of disturbance by human activity and of influence of sea salts. Haines and Akielaszek (1983) found that chloride concentrations were a poor indicator of human disturbance for New England waters. They also found a strong inverse relationship between chloride and distance to the seacoast, and hence used chloride concentration as a correction for the ionic contribution of marine aerosols. This correction technique was suggested by Wright and Gjessing (1976), who estimated seawater sulfate by assuming that all the chloride comes from seawater and that the amount of sulfate attributable to sea salts is proportional to the sulfate/chloride ratio in seawater. The seawater contribution of the other ions can be estimated in similar fashion. Wright and Gjessing (1976) suggested that the correction was important for areas near the coast but relatively minor for inland lakes. Also, this technique involves the assumption that no sulfate is retained or released by soils.

We believe that the seaspray contribution to lakes in eastern North America is less than the contribution to lakes in Scandinavia (where Wright and Gjessing worked) due to our

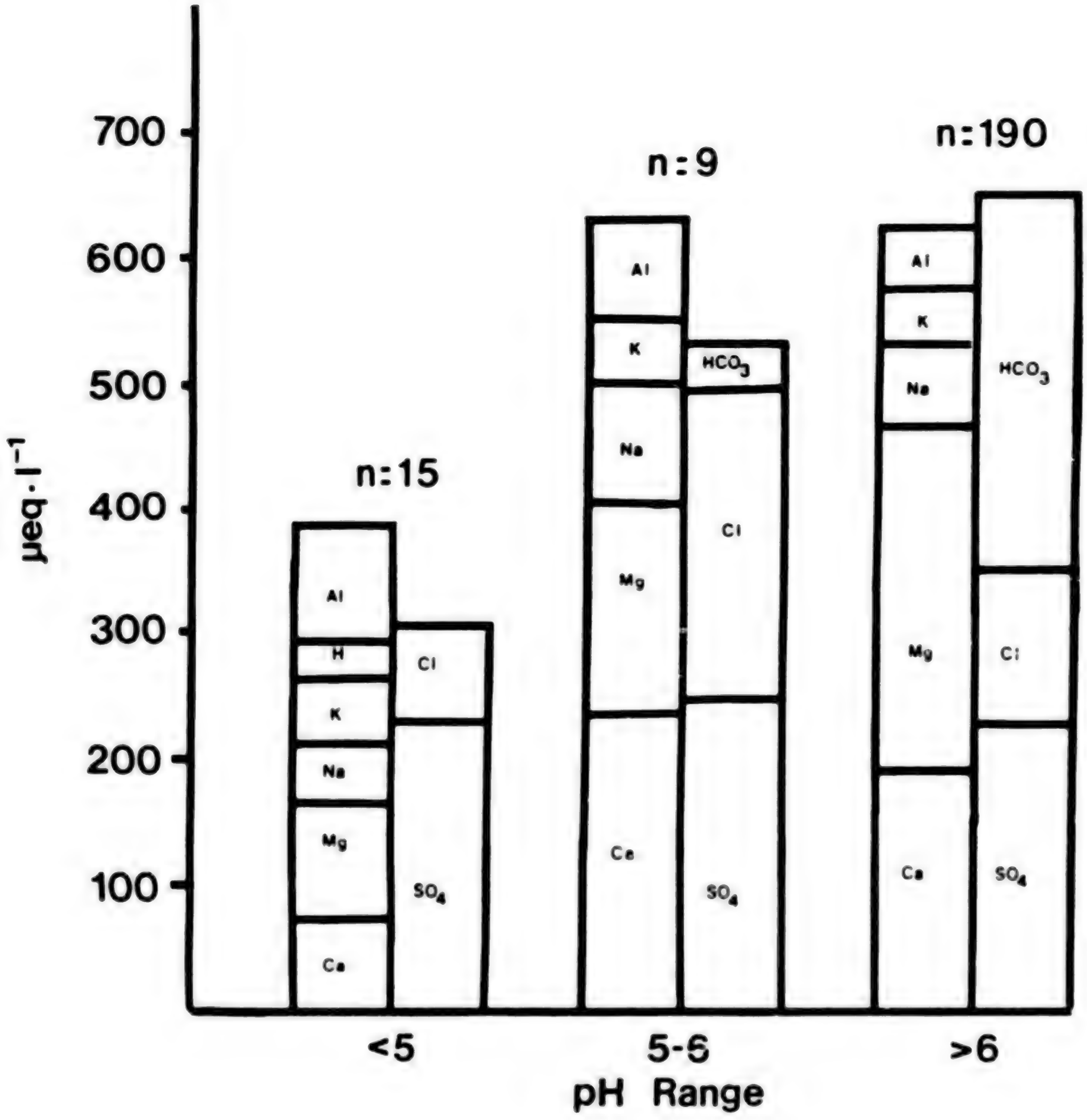

Figure 12. Mean ionic composition of sampled waters classified by pH range. For each water, data are means of duplicate analyses and of all depths sampled. (N = number of waters in each range).

prevailing westerly winds. Our data do not show a strong correlation between chloride or conductivity and distance to the seacoast. We used the ratio of 55% Cl to 7.7% SO_4, giving a 14% correction to be subtracted for sulfate from marine aerosols; i.e., nonmarine SO_4 = total SO_4 - 0.14 Cl. Also, nonmarine Ca = total Ca - 0.021 Cl and nonmarine Mg = total Mg - 0.067 Cl (Sverdrup et al. 1942). In the following sections we have selectively included, and so labeled, both corrected ("nonmarine") and uncorrected data.

Chloride concentrations in our final set of waters ranged from 1 to 473 μeq/l, with a mean of 124. Chloride was positively ($p = 0.0001$) correlated with disturbance, alkalinity, calcium, magnesium, conductivity, sodium, and sulfate, and negatively correlated with elevation. The latter is to be expected if higher elevation, headwater streams tend to be both less disturbed and more sensitive to acidification. Of the ten waters from our final set that were highest in chloride, none were near the seacoast and all but two had high disturbance codes. One case with low disturbance was the largest lake sampled (684 ha), which is a limited-access water supply but lies near an area of commercial salt production (with possible underwater exposure to salt beds); the other was a stream.

Sulfate

Sulfate values ranged from 18 to 932 μeq/l (averages of duplicate analyses at all depths). Mean sulfate concentration for the entire study was 227 μeq/l. Sulfate was positively ($p = 0.001$) correlated with alkalinity, conductivity, calcium, chloride, magnesium, manganese, and sodium; but was less strongly correlated with disturbance ($p = 0.07$). It had a weak inverse correlation with calcite saturation index. All these relations are as expected, and there is no evidence of any significant contribution from marine aerosols. When corrected for possible marine aerosol contribution in the manner of the New England study (Haines and Akielaszek 1983), our sulfate values were independent of chloride.

The concentrations of sulfate found in the Middle Atlantic States are higher than those reported for some other areas where precipitation is acidic, and much higher than those for areas with nonacidic precipitation (Table 13). As in the New England study, neither total nor nonmarine sulfate was significantly correlated with hydrogen ion concentration ($r = 0.026$, 0.029 respectively, $p = 0.5$). Like the New England results, our calcium and calcium+magnesium values were weakly correlated with sulfate ($r = 0.384$, 0.464 respectively, $p = 0.0001$).

Table 13. Concentrations of Sulfate (µeq/l) Reported from Surface Waters by Regional Surveys

		Total Sulfate		Nonmarine Sulfate		
Region	n	mean	s.d.	mean	s.d.	Reference
Areas where precipitation averages ≤ pH 4.6						
Middle Atlantic	218	227	161	211	158	This study
New England	226	138	51	127	48	Haines and Akielaszek 1983
South Norway	26	99	33	92	-	Gjessing et al. 1976
West Sweden	6	200	70	180	-	Grahn et al. 1974
Scotland	72	178	91	148	76	Wright and Gjessing 1976
Nova Scotia	16	152	28	117	25	Watt et al. 1979
Central Ontario	15	198	97	-	-	Dillon et al. 1978
Sudbury, Ontario	4	804	292	800	290	Scheider et al. 1975
La Cloche Mountains	4	287	42	285	41	Beamish 1976
Areas where precipitation averages > pH 4.6						
Central Norway	52	65	34	63	-	Gjessing et al. 1976
Western Ontario	7	63	-	58	-	Armstrong and Schindler 1971

Although all stations in the coastal areas of our study (New Jersey, Delaware, and eastern Maryland) showed sulfate levels above 100 µeq/l (Figure 13), this was also the case in several noncoastal areas (western New York, western Pennsylvania, western West Virginia; in general the Allegheny Plateau). A map of acid deposition over the region (Figure 8) shows that except for a small area of high deposition in the New York-New Jersey-Pennsylvania boundary area, deposition over the study area is relatively uniform. The variations in sulfate are probably more dependent on geological factors such as gypsum or pyrite deposits than on acidic deposition.

Calcium and Magnesium

We discuss calcium and magnesium together due to their similar origin and behavior. The sum of calcium and magnesium was correlated with alkalinity ($r = 0.640$, $p = 0.0001$), but not as strongly as in the New England study ($r = 0.95$) (Haines and Akielaszek 1983) nor as in Henriksen (1980) ($r = 0.98$). This may be due to the influence of some higher alkalinity waters on our data. The regression equation of our data (Figure 14) is alkalinity = 0.42 (Ca+Mg) + 75.9 (both in µeq/l) ($R^2 = 0.409$, $p = 0.0001$). This intercept (+75.9) is considerably higher than those reported in the above-mentioned studies, reflecting the generally higher level of alkalinity in the Middle Atlantic area.

When the streams and impoundments are removed from our data, leaving only "natural" lakes, the intercept drops to 23, still not as low as those of the New England study (-55) (Haines and Akielaszek 1983) and Henriksen's (1980) study of data from areas relatively unaffected by acid precipitation. The slope of our data is lower than for either of the above studies, suggesting a lesser role of calcium+magnesium in the higher alkalinity waters of our area. This is similar to the observations of Almer et al. (1978), that the alkalinity:(Ca+Mg) relationship was near 1:1 where sulfur deposition was low, but less than 1:1 where deposition was high. Calcium concentrations for Middle Atlantic States waters are compared with those found in studies of other areas in Table 14.

Aluminum and Manganese

Aluminum was not significantly correlated with pH or hydrogen ion concentration ($r = -0.166$, $p > 0.01$ and $r = 0.143$, $p > 0.03$, respectively). As expected, high aluminum concentrations were generally found in low pH waters, but there were enough

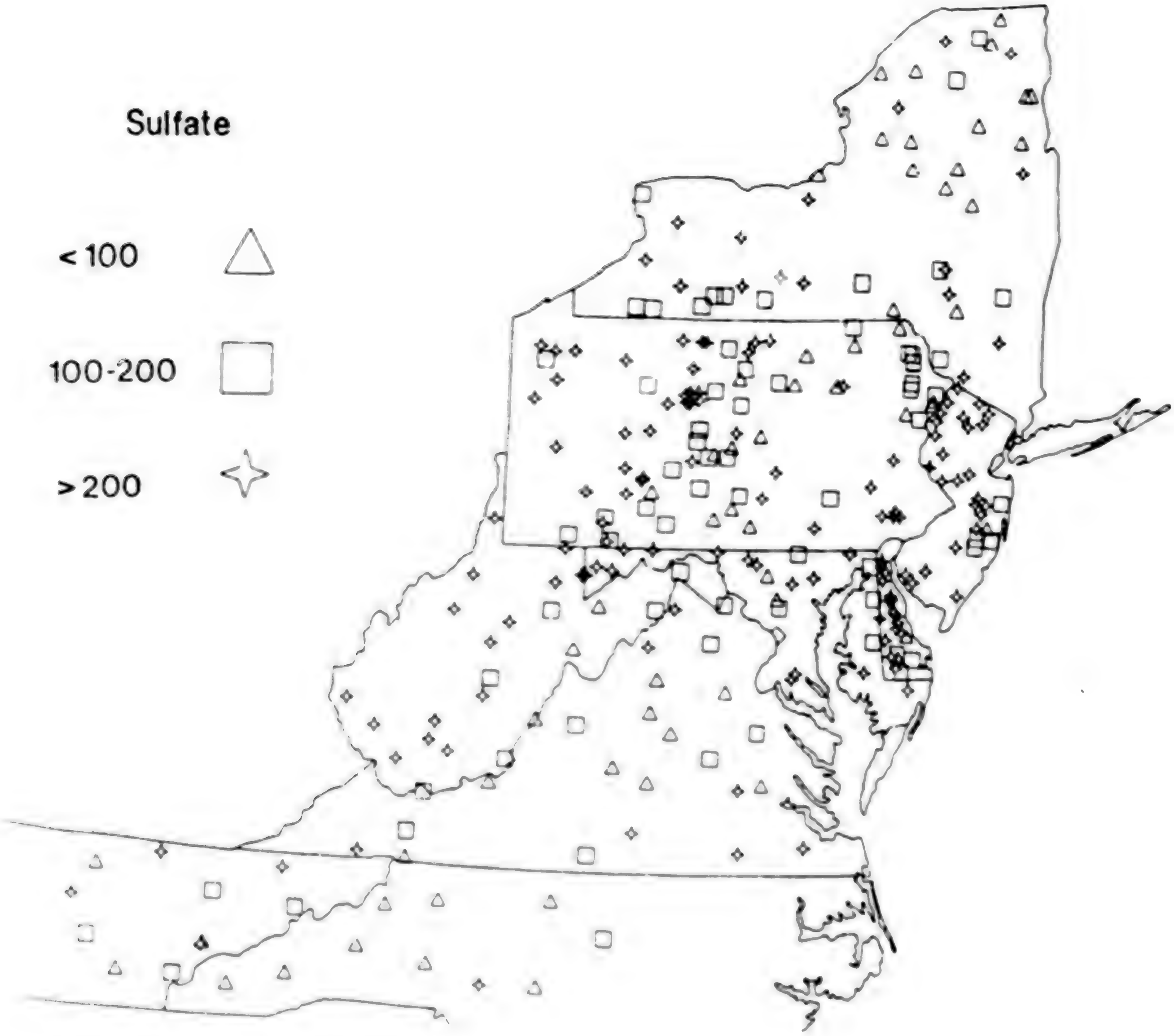

Figure 13. Map showing distribution of sites by sulfate concentration. Values in µeq/l.

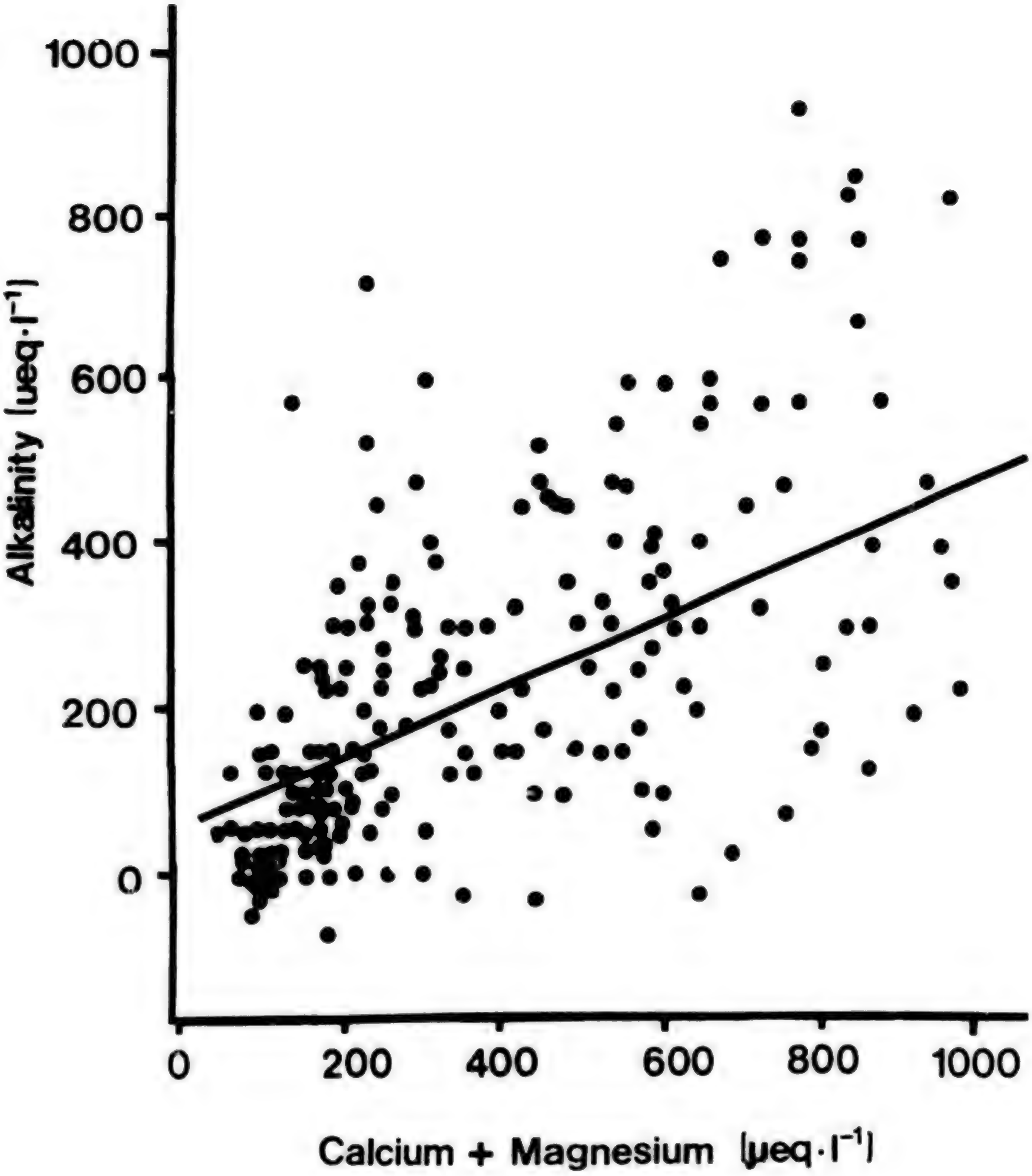

Figure 14. Relation of alkalinity to calcium + magnesium for 218 sampled waters (one point hidden). Regression equation is alkalinity = 0.418(Ca+Mg) + 75.99 (R^2 = 0.409, p = 0.0001).

Table 14. Concentrations of Calcium Reported from Surface Waters by Regional Surveys (Modified from Haines and Akielaszek (1983))

Region	n	Calcium content, µeq/l			Reference
		Mean	S.D.	Range	
Areas where precipitation averages ≤ pH 4.6)					
Middle Atlantic	218	279	242	21-1279	This study
- lakes only	45	321	255	43-1086	
- streams only	85	269	248	25-1279	
- impoundments only	88	266	229	21-1031	
New England	226	270	395	16-2300	Haines and Akielaszek 1983
South Norway	26	57	33	-	Gjessing et al. 1976
Nova Scotia	16	124	98	42-453	Watt et al. 1979
Scotland	72	239	371	14-1815	Wright and Henriksen 1980
Areas where precipitation averages > pH 4.6)					
World average	-	239	-	-	Henriksen 1980
Central Norway	52	139	110	-	Gjessing et al. 1976
Western Ontario	40	80	-	30-225	Armstrong and Schindler 1971

exceptions to prevent a showing of statistical significance. The regression equation for our waters is log Al (µeq/l) = 2.83-0.23 pH (R^2 = 0.048, p = 0.0011). Both this intercept and slope are lower than those reported by other regional surveys (see Table 12 of Haines and Akielaszek 1983). In general, however, our aluminum values were higher than those found in New England, ranging from 0 to 395 µeq/l, with a mean of 46.8. When the "natural" lakes or the streams are separated from the rest of our data, the relationship for each alone is only slightly stronger (R^2 = 0.123 and 0.114 respectively, p = 0.001). Waters with high aluminum concentrations were widely distributed throughout our study area (Figure 15). Only six of 218 stations (2.8%) had aluminum concentrations over 200 µeq/l, and only one of these was at a pH below 5.5.[7] This is the pH level below which elevated aluminum concentrations are considered toxic to some species of fish (Schofield and Trojnar 1980).

Although Haines and Akielaszek (1983) felt that the similarity of relations between pH and aluminum concentration in studies reviewed by them would enable the prediction of aluminum concentration from pH in any region, this would apparently not be the case in the Middle Atlantic States. This may be due to the generally higher ionic content, leading to more interferences, and/or to the generally greater complexity of bedrock and soil types in our area.

Manganese and aluminum are chemically similar, and our results for the manganese-pH relation were similar to those for aluminum. The regression equation is $\log_{10}$Mn = 0.11-0.045 pH, (R^2 = 0.0017, p = 0.03), a weaker relationship than that for aluminum. Haines and Akielaszek (1983) found a similar lack of correlation between manganese and pH in New England waters. Manganese values in our study ranged from 0 to 52 µeq/l, with a mean of only 3.2, much lower than the aluminum concentrations.

Neither aluminum nor manganese was strongly correlated with alkalinity (r = -0.166, 0.181 and p = 0.0140, 0.0076 respectively), nor were aluminum and manganese significantly correlated with each other (r = -0.055, p = 0.416) despite their chemical similarity.

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[7] Note that in their discussion in the corresponding section, Haines and Akielaszek (1983) used different units of concentration.

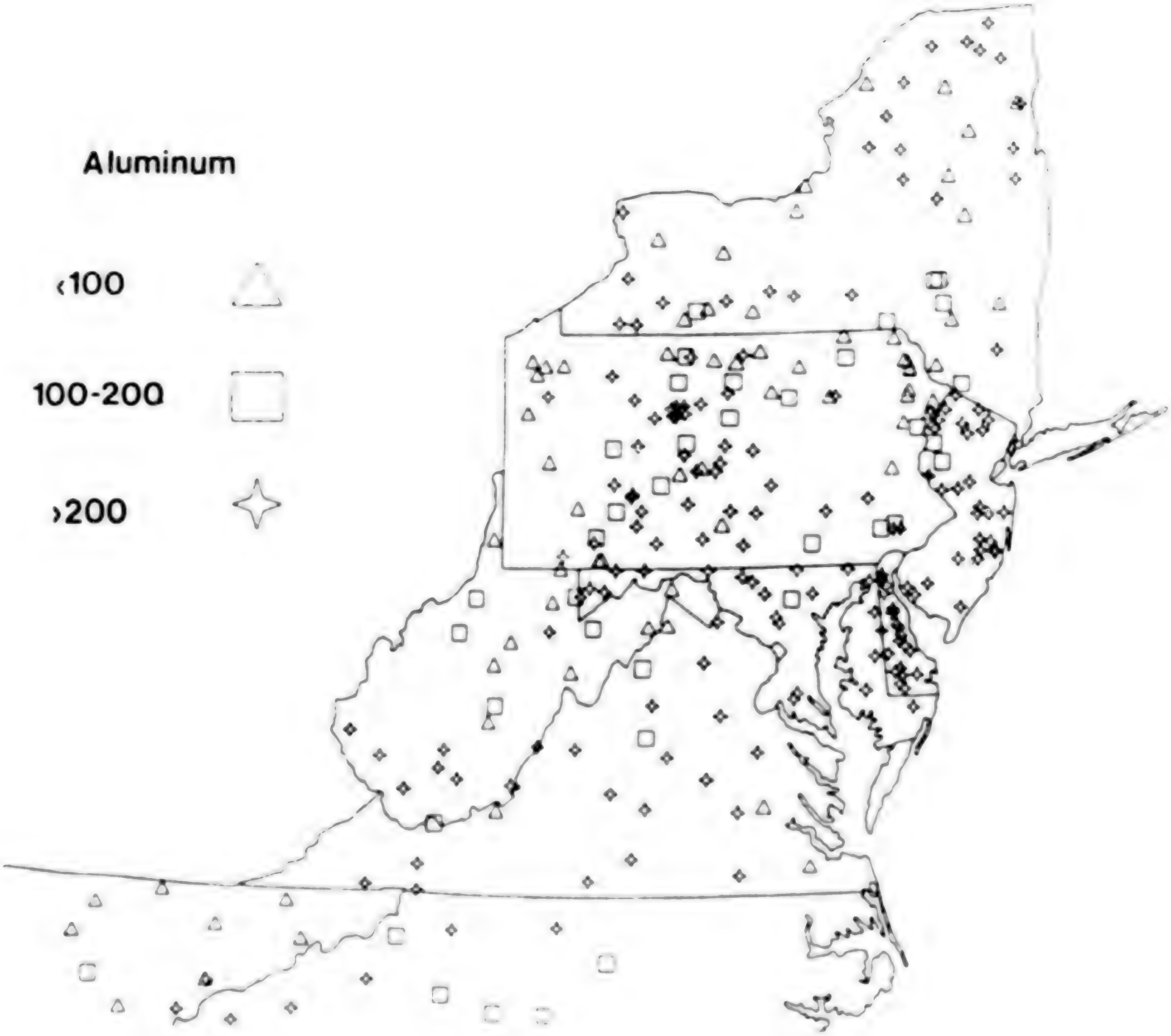

Figure 15. Map showing distribution of sampling sites by aluminum concentration in μeq/l. Data are means of duplicate analyses and of surface and bottom samples where taken.

Precipitation Chemistry

As shown in Figure 8, our study area had some variation in acid loading, but differences in bedrock, soils, and other influences masked any relationship which might exist between acid loading and water chemistry. A loading index was derived from the product of mean annual weighted precipitation pH (National Atmospheric Deposition Program 1984) and annual rainfall (from state climatological summaries for the year of sampling) (values listed in Appendix A). Both this index and its logarithm were tested against pH, alkalinity, elevation, conductivity, aluminum, calcium, chloride, color, and sulfate. In all cases the correlation was insignificant ($r < 0.02$).

PHYSICAL FACTORS

Elevation

Neither pH nor alkalinity was significantly correlated with elevation, although 24 of the 32 stations at elevations greater than 590 m had alkalinities below 200 µeq/l, the normal "cutoff point" for sensitivity. Neither was there any significant relationship between elevation and bedrock sensitivity, soil sensitivity or disturbance. It was noted, however, that all 11 stations on bedrock class I (very low acid neutralizing capacity) occurred in the lower half of the elevation range (< 590 M). This was somewhat contrary to our expectations, and appeared to be due to their location on the lower slopes of the poorly buffered rock areas. Most such areas in the Middle Atlantic States occur on hill and mountain tops where permanent water bodies are rare. There were strong negative correlations between elevation and chloride and conductivity ($r = -0.512, -0.451$ respectively, $p = 0.0001$).

As did Haines and Akielaszek (1983) in New England, we found acidic waters at low elevations, and waters with pH less than 5.5 (some below 5.0) at elevations from near sea level to over 1,000 m. We also found 21 waters with pH greater than 6.5 at elevations above 590 m; such waters seldom occurred in the New England study. Although it is certainly true that higher elevation areas usually have thin soil and sensitive bedrock, other factors (perhaps disturbance) apparently prevent these from being dominant influences on the chemistry of Middle Atlantic waters. This is in contrast to the situation in Norway (Wright and Snekvik 1978) where acidic lakes are rare at lower elevations, apparently due to the presence of easily weathered sedimentary bedrock.

Size

Neither pH nor alkalinity was significantly correlated with lake or pond area or stream width. Most of the natural lakes sampled were less than 50 ha in area (mean 47) and had pH below 7. Most of the impoundments were also less than 50 ha in area (mean 36), and their mean pH's tended to be lower than those of the "natural" lakes. Most small lakes had low alkalinity, but there were numerous small, higher alkalinity lakes and a few large, low alkalinity lakes.

Stream width is related only imprecisely to discharge or other measures which might be expected to reflect acid neutralizing capacity. Only six of our 85 stream stations had widths greater than 10 m; five of these six had pH greater than 7.5, and their alkalinities ranged from 227 to 842 µeq/l. It is generally true that wider streams have larger drainage areas, so that greater buffering by natural processes in the watershed and, possibly, human influence are expected. A high negative correlation has been found between stream width and acidification in Pennsylvania streams (Fred Johnson, Pennsylvania Fish Commission, Harrisburg; unpublished).

Hydrology Type

Both natural lakes and impoundments were separated into two types - seepage lakes (with no inlet) and drainage lakes (with inlet). In general, seepage lakes occurred at higher elevations, were smaller, and were less disturbed, but most chemical factors were not significantly different between the two types (Table 15).

The chemical factors measured, except alkalinity and calcium, were higher in the drainage lakes, probably reflecting leaching from the upstream watershed as well as the immediate lake basin. The differences, however, were not statistically significant. Drainage lakes were generally lower in elevation, larger, and had higher disturbance values, as might be expected. These differences are probably responsible for the higher ionic concentrations observed in the drainage lakes. Eilers et al. (1983) found that in northern Wisconsin, lake hydrology was a

Table 15. Chemical and Physical Factors for Lakes Classified by Hydrology Type. "*p*" is the probability that means are drawn from the same population (t-test of one-way analysis of variance). (No significant differences found)

	Hydrology type				
Factor	Drainage (n=119)		Seepage (n=14)		
	Mean	S.D.	Mean	S.D.	*p*
pH, units (from H+ conc.)	5.6	0.9	6.7	0.6	0.61
alkalinity, µeq/l	256	227	360	303	0.70
conductivity, µS/cm	71	40	65	38	0.22
calcite sat. index, units	2.7	1.3	2.5	1.2	0.65
calcium, µeq/l	281	242	317	215	0.49
magnesium, µeq/l	182	151	152	124	0.28
sodium, µeq/l	67	53	48	64	0.49
potassium, µeq/l	47	27	31	27	0.25
aluminum, µeq/l	48	56	14	12	0.04
manganese, µeq/l	4	8	5	5	0.69
chloride, µeq/l	141	131	50	55	0.27
sulfate, µeq/l	233	173	208	185	0.21
color, Pt-Co units	7.0	5.6	5.3	2.8	0.50
Secchi disc, m	1.8	1.2	1.9	1.3	0.56
disturbance, units	3.0	0.9	2.6	0.9	0.06
elevation, m MSL	285	238	428	209	0.12
area, ha	42	84	24	31	0.22

significant factor in water chemistry; but Haines and Akielaszek (1983) did not find any significant effect of hydrology in New England. Differences between the chemistry of lakes and streams (Table 16) were significant only for calcite saturation index, manganese, color, and disturbance.

Haines and Akielaszek (1983) also found that streams were higher in pH than were lakes, but the only other ionic

Table 16. Chemical and Physical Factors for Lakes and Streams. "*p*" is the probability that means are drawn from the same population (t-test of one-way analysis of variance)

Factor	Lakes (n=133)		Streams (n=85)		*p*
	Mean	S.D.	Mean	S.D.	
pH, units (based on H^+ conc.)	5.6	0.9	5.7	1.0	0.06
alkalinity, µeq/l	267	237	263	240	0.73
conductivity, µS/cm	70	39	69	38	0.42
calcite sat. index, units	2.6	1.3	2.3	1.3	0.09
calcium, µeq/l	284	238	269	248	0.58
magnesium, µeq/l	179	148	166	130	0.72
sodium, µeq/l	66	54	68	68	0.83
potassium, µeq/l	46	27	47	28	0.64
aluminum, µeq/l	44	54	51	61	0.53
manganese, µeq/l	4	8	1	3	0.00
chloride, µeq/l	134	128	112	110	0.90
sulfate, µeq/l	230	174	222	140	0.44
color, Pt-Co units	6.8	5.4	4.2	3.8	0.00
Secchi disc, m	1.8	1.2	NA	NA	NA
disturbance, units	3.0	0.9	2.6	0.9	0.01
elevation, m MSL	300	238	343	211	0.33
area, ha; or width, m	40	80	5.7	5.1	NA

concentration differences between streams and lakes in their study were in sodium and potassium rather than in manganese. It seems unlikely that any of these differences are of importance in controlling vulnerability to acidification, thus we have pooled data from all waters for many of our analyses.

Sharpe et al. (1984) found that pH, alkalinity, and dissolved aluminum were functions of stream discharge. If true for our streams, this would indicate that the conditions we observed would be influenced by the flow existing at the time we sampled. This problem probably exists for lakes as well but to a lesser extent. Unfortunately, neither discharge data nor the resources to do periodic sampling were available to us.

Stream Order

Average width increased with stream order, but no significant (at the 0.05 level) differences were found among streams of different orders for any of the characteristics measured, except disturbance. There was, however, a general increasing trend in content of calcium and chloride, and a decrease in calcite saturation index and elevation with increasing stream order (Table 17). This is the expected pattern, due to the larger, more varied watersheds of higher order streams. Johnson (unpublished) examined 1,812 coldwater stream sections in Pennsylvania and found a high negative correlation between stream order and three measures of acidification (pH $\leq$ 6, alkalinity $\leq$ 5 ppm, alkalinity $\leq$ 10 ppm).

Table 17. Chemical and Physical Factors for Streams by Stream Order. Means with same following letter are significantly different (one-way analysis of variance with Scheffe's comparison, *p* <0.05)

Factor	Stream order			
	1 (n=18)	2 (n=35)	3 (n=21)	4 (n=11)
pH, units	5.5	5.6	6.1	5.9
alkalinity, µeq/l	279	215	280	356
conductivity, µS/cm	66	61	69	95
calcite sat. index, units	2.2	2.5	2.3	1.5
calcium, µeq/l	213	261	261	407
magnesium, µeq/l	144	175	153	197
sodium, µeq/l	65	82	53	54
potassium, µeq/l	49	59	43	34
aluminum, µeq/l	53	64	38	26
manganese, µeq/l	1	1	2	1
chloride, µeq/l	70	104	107	207
sulfate, µeq/l	236	223	213	213
color, Pt-Co units	2.6	4.6	4.4	5.2
disturbance, units	2.4	2.3a	2.9	3.7a
elevation, m MSL	405	374	335	164
width, m	2.9	4.3	6.1	14.1

Bedrock Classes

Analysis of chemical results compared among bedrock sensitivity classes showed significant differences only in alkalinity and potassium (Table 18). This is similar to the results from the New England study except that they found significant differences in pH, calcium, conductivity, and calcite saturation index as well. There was no steady change in any factor from bedrock class I (very low acid neutralizing capacity) to IV (very high acid neutralizing capacity) as might have been expected. This may be related to the fact noted above (under Elevation) that the class I bedrock stations were not at the highest elevations (all were less than 550 m). Due to the relatively small number of sampling sites on class I bedrock, it is not advisable to draw conclusions from these data concerning the influence of interactions between bedrock and elevation on water chemistry. The pH of waters located over bedrock of class II or III varied over the whole range 4-8 (Figure 16). Only waters with pH above 6.25 were found over bedrock of class IV, and, unexpectedly, over bedrock of class I.

Examination of the relationship between bedrock and alkalinity levels (Figure 17) yields a similar impression. Although class I bedrock has the lowest acid neutralizing capacity, no waters with very low alkalinity (< 75 µeq/l) occurred in class I bedrock areas. Most waters in class II bedrock areas had low alkalinities, and waters in classes III and IV bedrock areas had alkalinities over nearly the full range considered. Thus even though many waters did reflect the relative acid neutralizing capacity of their underlying bedrock, the relationship was not consistent. Haines and Akielaszek (1983) obtained similar results in New England. They pointed out that the bedrock classes proposed by Hendrey et al. (1980) are related to chemical factors associated with acid neutralizing capacity and acidity but not to other factors which might influence water chemistry.

Because of the lack of significant differences between waters on bedrock classes I and II and similarly between III and IV, classes I and II were pooled and classes III and IV were pooled for further statistical analysis. Class I-II was termed "sensitive" and class III-IV was termed "nonsensitive." Also, waters with alkalinity of 200 µeq/l or less were termed "sensitive" and those higher in alkalinity were termed "nonsensitive." A similar grouping was done for pH, with the division placed at pH 6.75. We tested the effect of bedrock on

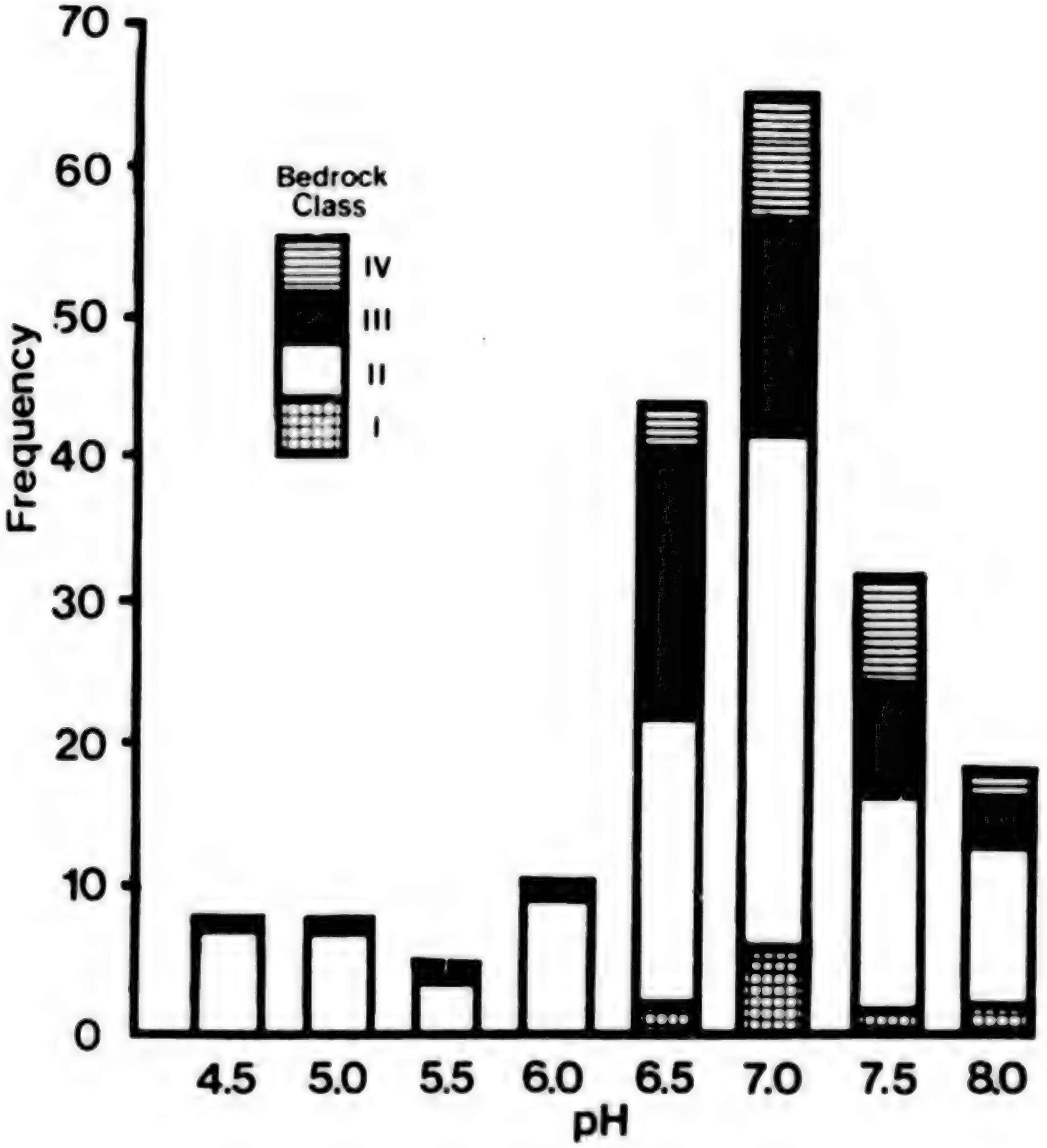

Figure 16. Frequency distribution of waters by bedrock geology in pH intervals. pH values listed are midpoints of ranges of 0.5 unit.

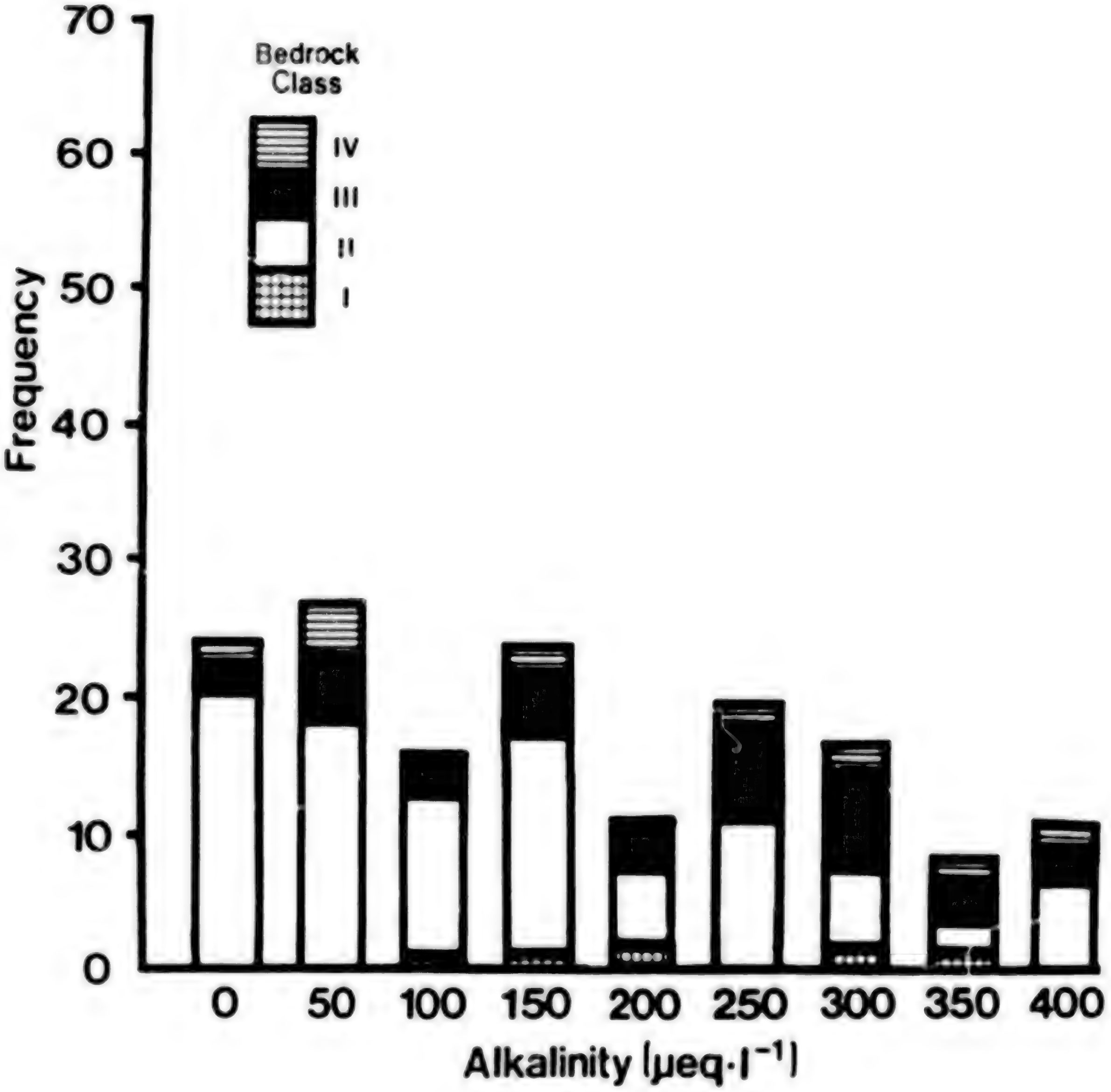

Figure 17. Frequency distribution of waters by bedrock geology in alkalinity intervals. Alkalinity values listed are midpoints of ranges of 50 μeq/l.

Table 18. Chemical and Physical Factors for Waters Classified by Bedrock Geology. Bedrock classes are: I = very low acid neutralizing capacity; II = moderately low acid neutralizing capacity; III = moderately high acid neutralizing capacity; IV = very high acid neutralizing capacity (Hendrey et al. 1980). Means with the same following letter are significantly different (one-way analysis of variance with Scheffe's comparison, $p = 0.05$) (Three waters in class V omitted)

Factor	Bedrock class			
	I (n-11)	II (n=127)	III (n=54)	IV (n=23)
pH, units (from H^+ conc.)	6.9	5.5	6.1	7.2
alkalinity, µeq/l	424	229a	263	415a
conductivity, µS/cm	75	65	78	78
calcite sat. index, units	2.2	2.5	2.6	2.1
calcium, µeq/l	304	122	231	370
magnesium, µeq/l	206	175	165	165
sodium, µeq/l	109	70	62	43
potassium, µeq/l	69a	49	45	34a
aluminum, µeq/l	81	49	43	30
manganese, µeq/l	6	3	3	2
chloride, µeq/l	127	122	154	75
sulfate, µeq/l	210	228	233	238
color, Pt-Co units	5.4	5.6	7.3	4.2
disturbance, units	3.5	2.7	3.0	3.0
elevation, m	260	342	241	346
Secchi disc (lakes only), m	1.4	1.7	1.5	2.7

pH and alkalinity using several statistical measures based on contingency tables. The most useful of these were the *phi* measure (Sokal and Rohlf 1973) and the odds ratio (Bliss 1967; Fleiss 1973). The contingency table format allows us to ask the following questions:

1. Are the numbers of observations within categories any different than what would be expected due to chance alone?

2. Is there any significant association between the bedrock or soil class and the pH and/or alkalinity of the overlying waters?

3. What are the odds of observing a sensitive water, given that the bedrock or soil type is sensitive?

The general format of such tables is:

	Water category		
Predictor	Sensitive	Non-sensitive	Sum
Sensitive	n_{11}	n_{12}	$n_{1\cdot}$
Non-sensitive	n_{21}	n_{22}	$n_{2\cdot}$
Sum	$n_{\cdot 1}$	$n_{\cdot 2}$	$n_{\cdot\cdot}$

If the variables are fully independent, then the observed cell frequencies will be the products of their respective row and column marginal probabilities. Chi-square (X^2) is the usual statistic for testing the null hypothesis of independence in such tables. The association measure (*phi*) is also used to evaluate predictive usefulness; in general associations less than 0.35 are not considered particularly useful as predictors (Sokal and Rohlf 1973). Another, more appropriate measure is known as the odds ratio (Fleiss 1973). If A represents a sensitive bedrock or soil class and B represents a sensitive lake type, then the odds ratio (w) gives the odds, or chance, of observing B when A is present relative to the chance of observing B when A is absent.

These analyses for bedrock are summarized in Tables 19 and 20. The results agree with the earlier indications (Table 17) that bedrock is only a marginally useful predictor of the sensitivity of a water to acidification (based on pH and alkalinity). The odds of observing a sensitive lake in a sensitive bedrock area are only 1.1 to 1 and 1.9 to 1 for pH and alkalinity, respectively. Only in the case of alkalinity does the chi-square value indicate that the ratio is significantly different from 1.

Table 19. Relations Between Bedrock Sensitivity and Water Sensitivity Based on pH

Bedrock Classes	pH		Sum
	<6.75	>6.75	
I & II	54	84	138
III & IV	30	50	80
Sum	84	134	218

$X^2 = 0.057$
$(p = 0.812)$

phi = 0.016

$w = 1.071$
s.e.$(w) = 0.$

Table 20. Relations Between Bedrock Sensitivity and Water Sensitivity Based on Alkalinity

Bedrock Classes	Alkalinity		Sum
	<200	>200	
I & II	74	64	138
III & IV	30	50	80
Sum	104	114	218

$X^2 = 5.277$
$(p = 0.0216)$

phi = 0.156

$w = 1.927$
s.e.$(w) = 0.553$

Soil Classes

Results of chemical analyses of sampled waters grouped by soil class (i.e., soil cation exchange capacity of McFee (1980) as defined in Table 1) are presented in Table 21. Most factors exhibited a significant difference among soil classes, whereas in the New England study only calcium, chloride, sulfate, sodium, and alkalinity were significantly different. Although we have placed class SS1 second in rank in Table 21, waters there exhibit the lowest mean calcium concentration and alkalinity; they also have the highest mean calcite saturation index and lowest mean conductivity (along with those on class S2) and the lowest mean pH. On the other hand, our means for physical factors suggest that the order of sensitivity might be S2>SS1>SS2>NS, as we have presented it.

Table 21. Chemical and Physical Factors for Waters Classified by Soil Sensitivity. Soil Classes are: S1= sensitive; S2= sensitive <50%; SS1=slightly sensitive; SS2=slightly sensitive <50%, NS= non-sensitive. Means with the same following letter are significantly different (one-way analysis of variance with Scheffe's comparison, *p* = 0.05) (No waters were sampled on class S1 soil)

Factor	Soil class			
	S2 (n=39)	SS1 (n=86)	SS2 (n=46)	NS (n=47)
pH, units (from H^+conc.)	6.2	5.5	5.6	5.7
alkalinity, µeq/l	242	228	324	297
conductivity, µS/cm	57a	57ab	96a	78b
calcite sat. index, units	2.9	2.7	2.2	2.2
calcium, µeq/l	240	193ab	368b	379a
magnesium, µeq/l	106ab	142cd	241ad	223bc
sodium, µeq/l	34ac	58b	90ab	86c
potassium, µeq/l	34ab	50a	51b	48
aluminum, µeq/l	31a	63ab	44	32b
manganese, µeq/l	3	3	5	3
chloride, µeq/l	78ab	83cd	199bd	166ac
sulfate, µeq/l	183a	194b	325abc	229c
color, Pt-Co units	4.8	5.1	6.9	7.0
disturbance, units	2.5a	2.8	3.1a	2.9
elevation, m MSL	434ab	331c	217bc	293a
Secchi disc, m (lakes)	2.7a	1.8	1.5a	1.7

McFee's (1980) class definitions (Table 1) present problems of interpretation when we attempt to assign individual waters to a class on the map. For example, a lake may clearly be located in an area labeled "S2" on the McFee map, but the full definition of "S2" is: "sensitive soils are significant, but cover less than 50% of the area." Is our lake thus on sensitive soil or not? Only a local, detailed survey of the soils around a water body can provide such information; even then the picture may be clouded by the presence of several adjacent soil types. Unknown local soil effects may mask relationships between soil class and water chemistry. Also, the maps at the scale available to us were not sufficiently precise to associate a given water with an exact soil class with certainty in every case. To a lesser extent, the same problem may exist for the bedrock classes. It should be noted that the original intent of McFee's (1980) study was not that the classes be used as we have, but to assess the proportions of total area in the eastern U.S. likely to be sensitive on the basis of soil cation exchange capacity.

The frequency distribution of pH of waters by soil classes (Figure 18) is quite similar to that for bedrock. The greatest numbers were in the interval pH 6.76-7.25, and classes SS1, SS2, and NS occurred in nearly all pH intervals. Class S2 occurred only above pH 4.75. Most, but not all, waters on soil class NS had pH of 6.25 or greater. This distribution was similar to that found by Haines and Akielaszek (1983) except that they had no waters on soil class S2. The relationship beteen soil classes and alkalinity (Figure 19) was not as skewed as it was for New England, except that the largest number of waters were in the highest and lowest alkalinity intervals (>375 and <25 μeq/l). All four soil types were represented in nearly every alkalinity interval.

Contingency tables were also developed for soil and water sensitivity on the bases of pH and alkalinity. As before, pH was divided above and below pH 6.75, and alkalinity above and below 200 μeq/l. For this analysis, soil classes S2, SS1, and SS2 were combined and termed "sensitive," and class NS alone was termed "nonsensitive." Results are given for pH and alkalinity in Tables 22 and 23, respectively. The contingency tables for soil class are not significantly different from what would be expected by chance alone. The odds ratios (1.2:1 for pH and 1.1:1 for alkalinity) both indicate that lake sensitivity is not strongly related to soil type.

Haines and Akielaszek (1983) found that the odds ratios for both bedrock and soil class provided good predictions of sensitivity, although bedrock was much better than soil. Kaplan et al. (1981) concluded that bedrock influenced water chemistry not directly but rather through soils. However, they used different classifications of bedrock and soil from ours, and

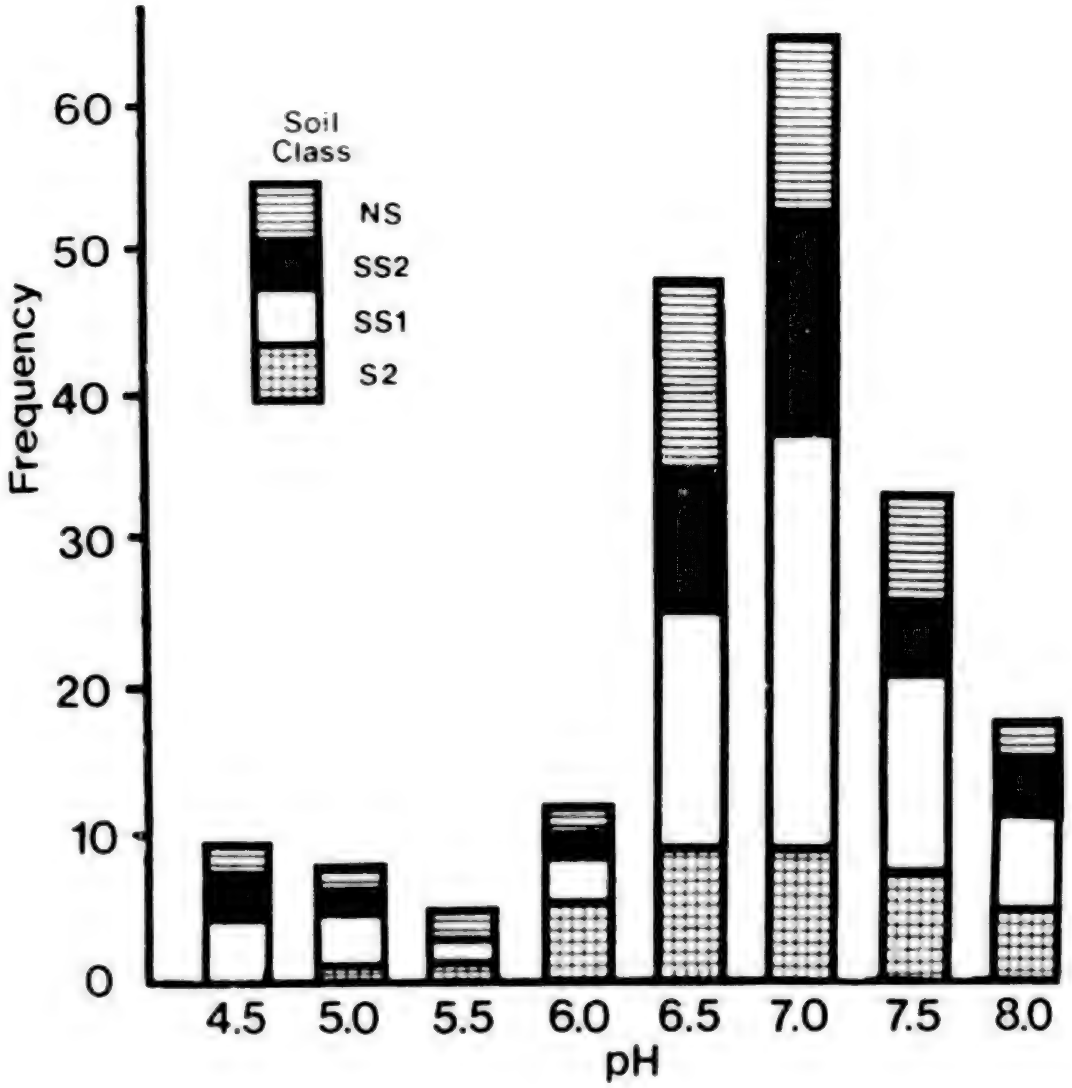

Figure 18. Frequency distribution of pH of waters by soil classes. pH figures given are midpoints of intervals of 0.5 pH.

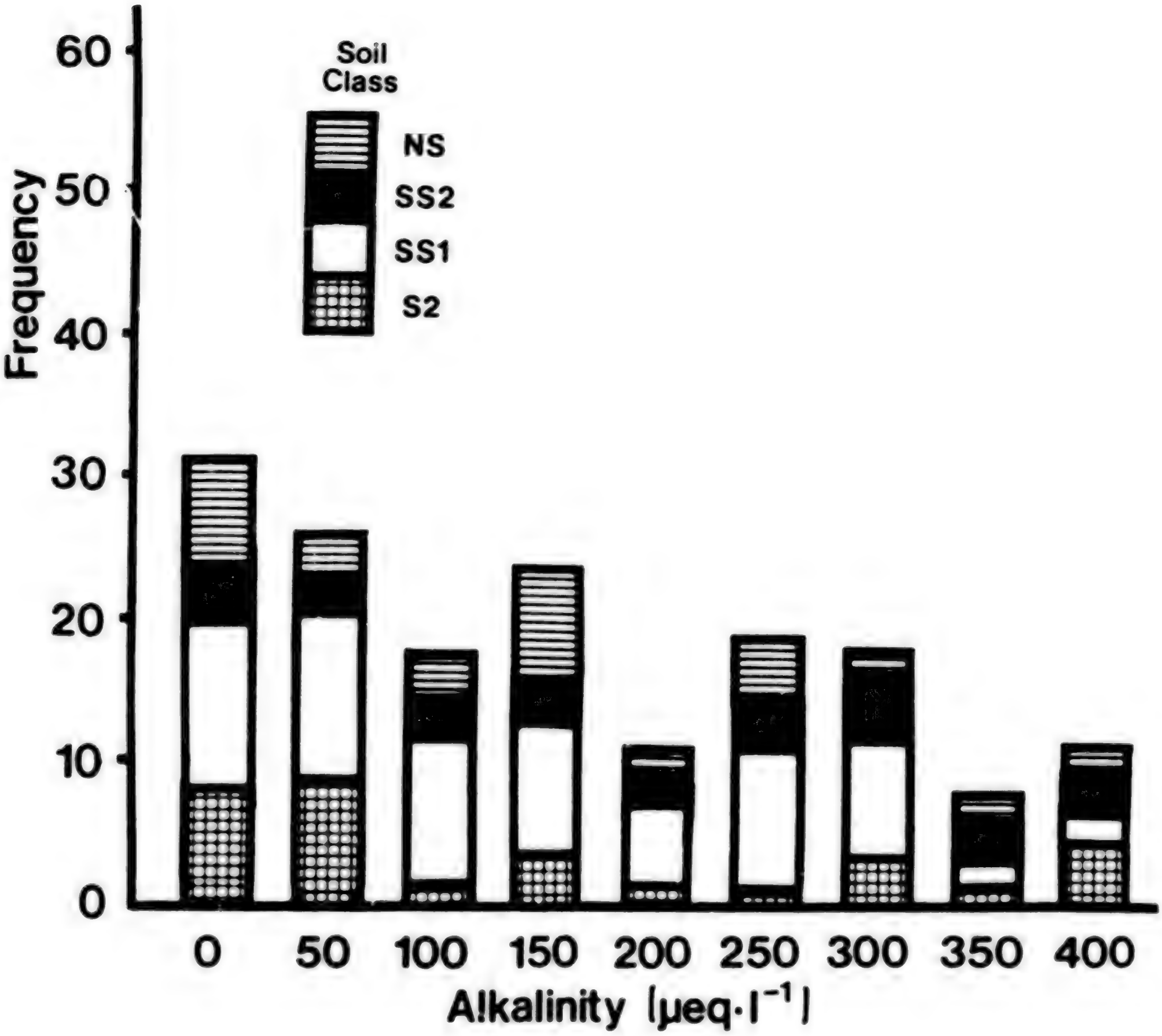

Figure 19. Frequency distribution of alkalinity of waters by soil classes. Alkalinities are midpoints of intervals of 50 μeq/l.

Table 22. Relations Between Soil Sensitivity and Water Sensitivity Based on pH

Soil Classes	pH		
	<6.75	>6.75	Sum
S2 + SS1 + SS2	20	27	171
NS	64	107	47
Sum	84	134	218

$X^2 = 0.409$
$(p = 0.5225)$

$phi = 0.043$

$w = 1.238$
s.e.(w) = 0.414

Table 23. Relations Between Soil Sensitivity and Water Sensitivity Based on Alkalinity

Soil Classes	Alkalinity, µeq/l		
	<200	>200	Sum
S2 + SS1 + SS2	23	24	47
NS	81	90	171
Sum	104	114	218

$X^2 = 0.036$
$(p = 0.8489)$

$phi = 0.013$

$w = 1.065$
s.e.(w) = 0.35

studied primarily lowland sites where the soils would be expected to be thicker than those in our study and the companion New England work. Thin soils such as are found at higher elevations would be expected to allow a greater influence of bedrock on water chemistry. Sensitive soils and sensitive bedrock may occur together and sometimes act synergistically in influencing (or failing to influence) the acidity of precipitation runoff, the chemistry of receiving waters, or both. Thus we again conclude that, at the presently available level of detail, knowledge of only the bedrock and soil conditions is not a sufficient basis for predicting the likelihood of acidification of a given water body, and that the published maps showing sensitive areas based on bedrock alone can be misleading.

Human Disturbance

The degree of human disturbance in the watershed was significantly related to elevation, pH, conductivity, and chloride at the 95% confidence level (Table 24). This was similar to the New England study results.

The least disturbed waters were at the highest elevations, and the most disturbed were at the lowest. For lakes, the Secchi disc transparency was higher in the least disturbed lakes and lower in those most disturbed, as expected. Most of the chemical factors closely related to acidification - alkalinity, calcite saturation index, calcium, magnesium, and sulfate - showed consistent trends, and pH was higher in classes 3 and 4 than in classes 1 and 2. Aluminum, potassium, sodium, color, and manganese were not related to disturbance in any consistent way. Unlike the New England results, color in our study was not a potential index of disturbance. Chloride, however, may have some use in this regard.

Human activities such as construction, waste disposal, farming, logging, and road travel result in exposure of soils and rock to increased leaching of chemical constituents, and also may increase the amount of surface runoff. This is, no doubt, the cause of these observed relations. Unlike Haines and Akielaszek (1983), we found no statistical evidence of a relationship between bedrock class and disturbance (Table 18), but soil classes S2 and SS2 were significantly related to disturbance (Table 21). The overall correlation between soil class and disturbance, however, was low ($r = 0.134$, $p = 0.048$).

MULTIVARIATE ANALYSES

In any study with as many variables as the present one, it is desirable to explore multivariate analysis techniques in order to clarify the importance of particular variables. We performed several such techniques of which the results of two are presented.

Principal Components Analysis

Principal components analysis is a multivariate technique for examining relationships among several quantitative variables. We used it to identify those chemical factors which seem to have the most influence on the overall water chemistry, and thus might

Table 24. Chemical and Physical Factors for Waters by Degree of Human Disturbance (for definitions of classes 1-4, see Table 2). Means with the same following letter are significantly different (One-way analysis of variance with Scheffe's comparison, $p = 0.05$)

Factor	Disturbance class			
	1 (n=21)	2 (n=51)	3 (n=88)	4 (n=58)
pH, units (from H^+ conc.)	5.2a	5.6	5.9a	5.8
alkalinity, µeq/l	144	222	273	334
conductivity, µS/cm	46a	61b	71	84ab
calcite sat. index, units	2.9	2.6	2.6	2.1
calcium, µeq/l	261	248	291	311
magnesium, µeq/l	122	151	172	215
sodium, µeq/l	56	52	70	77
potassium, µeq/l	45	46	47	49
aluminum, µeq/l	40	52	38	58
manganese, µeq/l	3	2	4	3
chloride, µeq/l	57a	78b	131	174ab
sulfate, µeq/l	174	209	240	244
color, Pt-Co units	4.9	5.4	6.2	6.1
Secchi disc (lakes only), m	1.8	2.3	1.8	1.5
elevation, m MSL	535a	399b	315	214ab

have value as predictors of vulnerability to acidification. Results of this analysis for the major chemical measurements of our study are presented in Table 25.

The first principal component accounts for the largest portion of the variance and is dominated by magnesium, calcium, chloride, sodium, and alkalinity. Sodium and chloride are not involved with acid neutralizing capacity or acidity, but may reflect disturbance or the presence of salt deposits in some watersheds. Alkalinity, calcium, and magnesium are closely related to acid neutralizing capacity. The second component is dominated by alkalinity and calcium, with aluminum and potassium showing an inverse influence. The third component is dominated by aluminum and potassium, and inversely by hydrogen ion, the significance of which is unclear. Results for the New England

Table 25. Principal Components Analysis of Chemical Factors

Variable	Principal Components		
	First	Second	Third
Cumulative percent of variance explained by component	25	40	48
Hydrogen ion	-0.07	-0.31	-0.40
Alkalinity	0.29	0.30	0.15
Aluminum	-0.01	-0.33	0.38
Calcium	0.35	0.17	-0.20
Chloride	0.32	-0.05	-0.09
Potassium	0.12	-0.43	0.35
Magnesium	0.39	0.03	-0.08
Sodium	0.30	-0.32	0.12
Sulfate	0.26	-0.02	-0.15

data were similar except that sodium and chloride were important only in the second component, and hydrogen ion (as pH) was important in the first component.

From these results, it appears again that alkalinity is potentially useful as a predictor, while calcium, magnesium, and sulfate are also strongly influential on the chemistry of the sampled waters. The principal components technique is relatively weak for this data since the first three components account for only 48 per cent of the variance.

Canonical Correlation Analysis

Canonical correlation is a technique for examining the relationship between two sets of variables by testing the hypothesis that each canonical correlation and all those smaller are actually equal to zero in the population. Given two sets of variables, a linear combination is found from each set, such that the correlation between the two combinations, called canonical variables, is maximized. This is called the first canonical correlation. The coefficients of the combinations are called canonical weights, and can be used to determine which variables have the most influence on the variance of the data set. Next a second set of canonical variables, uncorrelated with the first pair, is found to produce the second highest correlation coefficient. This process continues until the number of canonical variables equals the number of variables in the smaller group, but usually not all the pairs are used (SAS Institute 1982).

We compared chemical measurements to physical factors from our data using canonical correlation analysis. Only the first three canonical correlations showed reasonably high probability of being different from zero, and are presented in Table 26. The results show good correlations ($r_1 = 0.70$, $r_2 = 0.35$, $r_3 = 0.31$) between physical and chemical factors, all significant at the 0.05 level. Soil class and disturbance carry the highest weights among the physical factors, while chloride, sodium, and alkalinity dominate the chemical factors. This is the first case in our data analyses wherein soil appeared to be a stronger influence than bedrock.

We performed a canonical redundancy analysis (van den Wollenberg 1977) which examines how well the original variables can be predicted from the canonical variables. This analysis shows that neither of the first pair of canonical variables is a good overall predictor of the opposite set of variables, the proportions of variance explained being only 0.103 (chemical) and 0.135 (physical). The first three canonical variables together explain only 0.134 and 0.175 of the chemical and physical factor variances, respectively. The squared multiple correlations calculated as part of the redundancy analysis indicate that the first canonical variable of the physical factors has some predictive ability for chloride (0.313) and sodium (0.271) but little or none for the other ions. The first canonical variable of the chemical factors has some predictive power for elevation (0.392), but little else.

We conclude that canonical correlation analysis is not a strong predictive tool for use with our data, but in general does not contradict the conclusions drawn from our other methods.

HISTORICAL COMPARISONS

At least one set of historical data was found for 160 of the 278 waters in our sampling program. For the following analysis, we used unscreened data from our original set of 278 waters, but only a few comparisons involved waters not in the reduced

Table 26. Canonical Correlation Analysis of Standardized Chemical and Physical Factors

Factor	Canonical correlation		
	First	Second	Third
Canonical correlations (*p* (corr = 0))	0.70	0.35	0.31
Physical factor weights:			
size	0.09	0.40	0.10
elevation	-0.77	0.23	0.24
bedrock class	-0.19	0.74	0.14
soil class	0.27	0.17	0.94
disturbance	0.22	0.55	-0.50
Chemical measurement weights:			
hydrogen ion	0.22	-0.46	0.13
alkalinity	0.30	0.49	-0.73
aluminum	0.17	0.09	-0.45
calcium	-0.25	0.11	0.60
chloride	0.65	0.23	-0.36
potassium	-0.20	-0.52	-0.06
magnesium	0.07	-0.29	-0.64
manganese	0.17	-0.40	-0.23
sodium	0.64	-0.00	-0.09
sulfate	0.19	0.33	-0.04

(screened) set. In several cases multiple historical data points exist, bringing the total to about 350 sets of historical values. Most of these contained pH data, but many were lacking alkalinity data, and a few had alkalinity but not pH. The oldest data found were from 1930. A listing of all historical data obtained for each station is given in Appendix B.

pH Comparisons

We compared our pH data with the oldest available pH data for each station (Figure 20). The low coefficient of determination ($R^2 = 0.288$) indicates that the changes in pH over

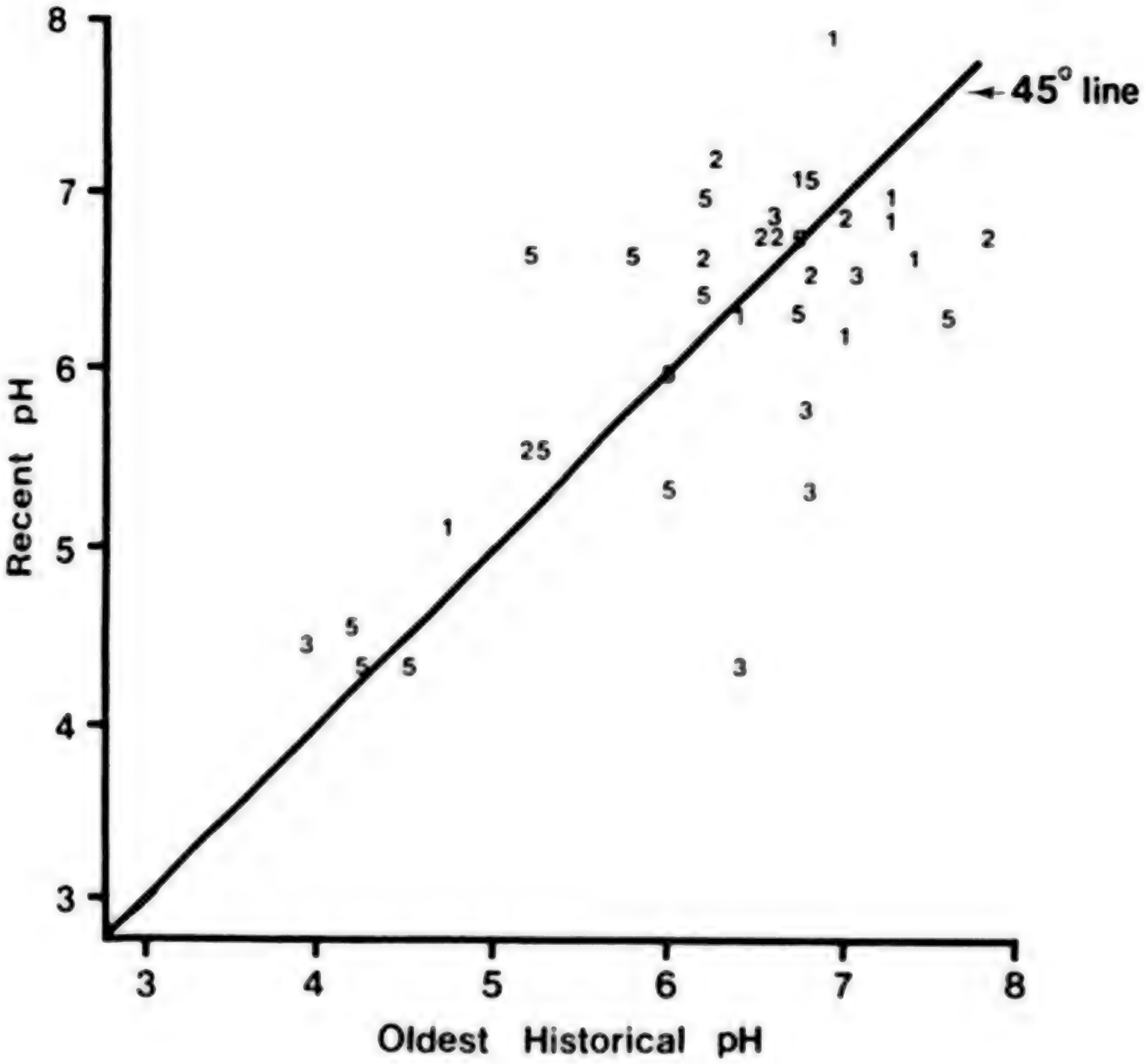

Figure 20. Recent (this study) pH value versus oldest value available for 36 locations. Diagonal line indicates equal pH. Waters with pH > 8, alkalinity > 250 μeq/l, or time span not greater than 2 years have been excluded. Numbers represent time between observations grouped as follows: 1 = 2-5 years; 2 = 6-10 years; 3 = 11-15 years; 4 = 16-20 years; 5 = >20 years.

time are not consistent among sites. Of the 160 waters, 62 (39%) decreased in pH and 98 (61%) remained the same or increased. These are nearly the opposite of the comparable figures for New England waters as reported by Haines and Akielaszek (1983). As pointed out earlier by Arnold et al. (1980), there are a number of factors, mostly related to man's activity, that can be expected to cause increases in the pH of waters over time, but few that cause a decrease in pH other than inputs of acid from precipitation or obvious pollution sources such as new coal mines in the watershed. In general, the greater incidence of human activity in the Middle Atlantic States compared with New England is probably an important reason for the higher number of cases in which pH or alkalinity increased.

The length of time between the oldest "historical" pH measurement and the measurement done by us at the same location varied from 1-50 years, with a mean of 17 years. We plotted change in pH against elapsed time in years for each site and found no significant trend ($R^2 = 0.0003$, $p = 0.73$). This analysis included the entire set of waters for which historical data were available, and indicates that there is no consistency in rate of change, if any, among the sampled waters. Many of these lakes have high acid neutralizing capacity and would not be expected to show much change in pH, even with significant inputs of acidity.

As any experienced field worker knows, measurement of accurate pH in the field, especially on poorly-buffered waters, is a task having limited and inconsistent success regardless of the method used. The historical data available to us sometimes specified the general method (electrometric or colorimetric) used and sometimes did not. Such information is not a sufficient basis for judging either the accuracy or the precision of the data. Furthermore, changing limnological conditions over a few hours or days, or between seasons, can cause significant changes in pH and thus render historical pH comparisons meaningless unless they involve numerous data points on the same water or large, consistent changes. Our experience leads us to conclude that the above analyses of changes and trends in the available data cannot be used to draw conclusions about overall trends because the accuracy of the historical data is unknown.

Alkalinity Comparisons

A more instructive approach is to look at changes in acid neutralizing capacity as represented by alkalinity. For these analyses, fixed endpoint alkalinity (by titration to pH 4.5) was used for our "recent" measurement, since considerable investigation by ourselves and other workers has indicated that almost all alkalinity data before approximately 1975 were produced by fixed endpoint methods. Kramer and Tessier (1982) and Haines and Akielaszek (1983) presented reviews of the literature and considerations involved in historical alkalinity comparisons. The fixed endpoint method often overestimates true alkalinity (Kramer and Tessier 1982). We compared the fixed and double endpoint alkalinities of our samples and found that they were highly correlated ($r = 0.9984$, $p < 0.01$), with the regression equation being double endpoint = 0.977 fixed endpoint - 25.3 ($R^2 = 0.997$, $p = 0.0001$). Thus the fixed endpoint historical alkalinity could be corrected for the overestimation by subtracting 25.3 µeq/l. This correction was virtually identical when the data were separated as natural lakes, streams, or impoundments. Haines and Akielaszek (1983), using a factor of 32 µeq/l, compared corrected historical data to their double endpoint data for New England waters; whereas we measured the fixed endpoint alkalinity and compared it directly with the historical data. Kramer and Tessier (1982) suggested that the true correction factor to be subtracted from alkalinity data obtained by methyl orange titration is 81 µeq/l. We were unable to determine exactly which of the historical data we obtained were done by methyl orange and which by electrometric titration, nor the exact endpoints used in most cases. Thus the results of these comparisons should be considered approximate.

The mean historical alkalinity for all 95 available comparisons was 697 µeq/l, and our mean "recent" alkalinity for the same waters was 489 µeq/l, or a decrease of 208 µeq/l (30%). As was done for pH, we plotted the change in alkalinity against the time in years between observations for each site and found no significant relationship ($R^2 = 0.0001$, $p = 0.88$). This indicates that the rate of decrease in alkalinity varies considerably among the sampled waters. Only 26 (23%) waters showed an increase or no change in alkalinity, while 87 (77%) decreased. Haines and Akielaszek (1983) found corresponding values of 30% and 70%, respectively, in New England. They reviewed several other studies which all showed decreases in mean alkalinity of waters in Sweden and the United States over the same time period as our data. Johnson (1984) examined data for 41 Pennsylvania streams surveyed by Pennsylvania Fish Commission personnel using the same techniques over a time span of about 15 years and showed that 92% decreased in alkalinity, from an average of 400 µeq/l to an average of 180 µeq/l.

In a number of articles on the "acid rain problem" (e. g., see papers by Hodanbosi, Frohliger, Smith and others in Kostik 1980; also Curtis 1980 and Hunton and Williams 1983) the

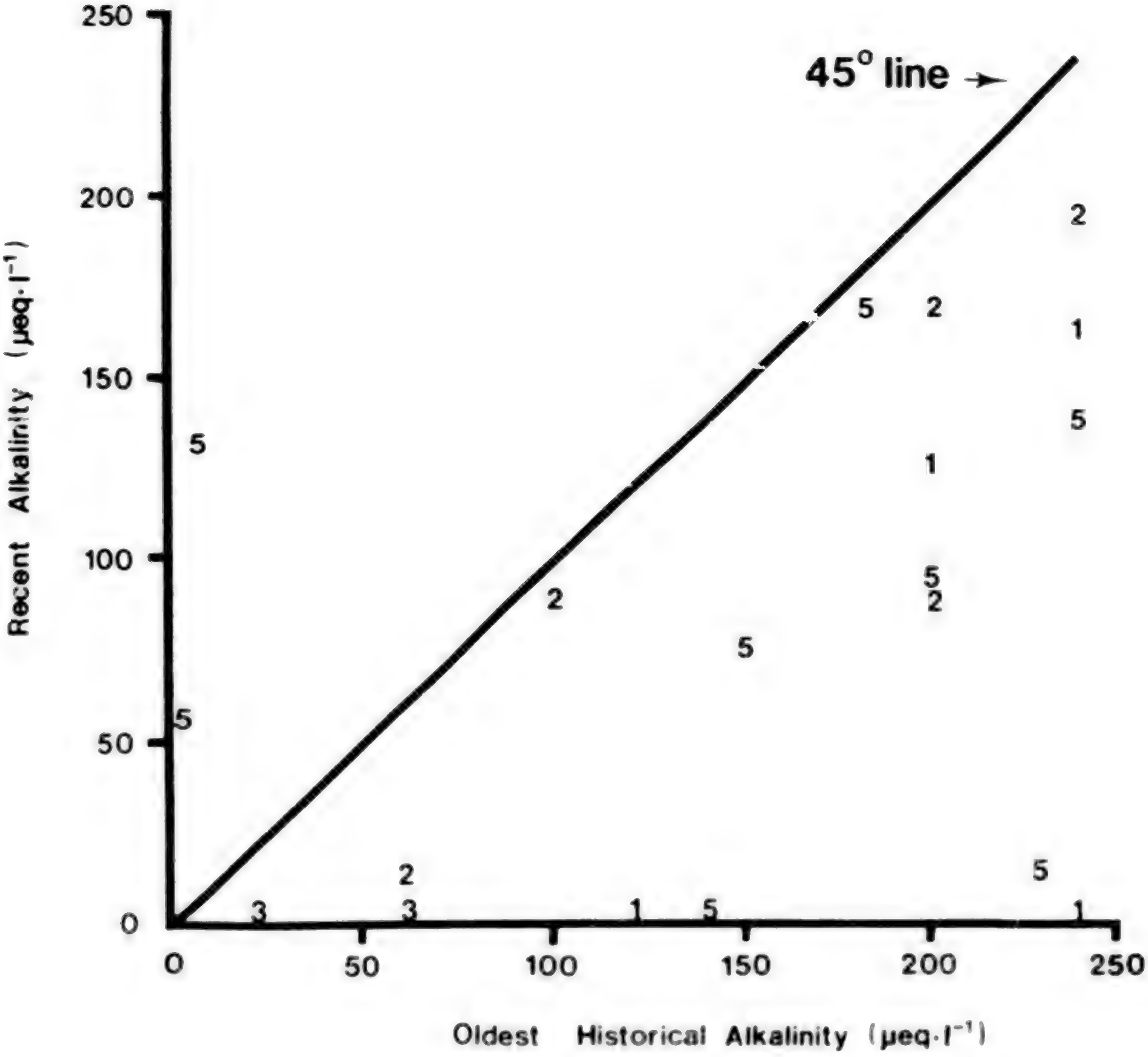

Figure 21. Recent (this study) fixed endpoint alkalinity value versus oldest available for 19 locations. Diagonal line indicates equal alkalinity (no change). Waters with time span not greater than 2 years have been excluded. Numbers represent time between observations grouped as follows: 1 = 2-5 years, 2 = 6-10 years, 3 = 11-15 years, 4 = 16-20 years, 5 = > 20 years.

assertion has been made that the problem is not real because few waters have shown a major change in pH. However, because of the bicarbonate buffering system, little change in pH is expected over a wide range of hydrogen ion loading. Thus alkalinity changes are a better index of acidification than are pH changes. Also, alkalinity is a better index of sensitivity to acidification at a given site, or to compare sensitivity between sites. Schofield (1982) determined the change of pH between historic and recent data for lakes in the Adirondack Mountains of New York, and compared it with recent calcium concentrations. He calculated that at a level of 100-125 μeq/l calcium, the bicarbonate buffering capacity would be lost and pH would decrease. This agreed well with the changes which he observed. We did a similar comparison and observed some similar results, but we also observed some increases in pH below 125 μeq/l calcium, and a few decreases at higher calcium levels. These exceptions were all cases where the time span of the historical comparison was quite long (10-20 or more years). The exceptions may also support a hypothesis that has been suggested by Coombs (Marjorie Coombs, Florida Department of Environmental Regulation, personal communication) and others - that as acid neutralizing capacity declines to critical levels, pH and other water chemistry measurements become highly variable among successive observations at a site. Only long-term periodic monitoring of such sites can test this hypothesis.

Although alkalinity is, in general, a more stable characteristic of a natural water than is pH, it can vary somewhat in time and space within a water body, especially a poorly buffered one. Thus, as in the case of pH, we feel that only large, consistent changes based on several data points for the same water are useful to suggest acidification based on historical data. Even data showing these characteristics can only be evaluated if the exact methodology and titration endpoints used are known so that appropriate correction factors can be applied as discussed above. These cautions and the small number of alkalinity comparisons available to us suggest that the data shown in Figure 21 should be considered only a suggestion that a decrease in alkalinity may have occurred in many waters of the Middle Atlantic States.

APPLICATION OF PROPOSED MODELS OF ACIDIFICATION

Several models and classification systems based on water chemistry have been proposed to determine and/or predict the degree of acidification of waters or their potential susceptibility to acidification. We applied several of these to our data as discussed below.

Sensitivity Classification

Altshuller and McBean (1979) proposed a classification by groupings under four common water chemistry measurements: alkalinity, bicarbonate concentration, calcium concentration, and conductivity. Since in our study bicarbonate was not determined separately from alkalinity we have not considered it here. We have also converted mg/l to µeq/l for consistency (Table 27).

Table 27. Sensitivity Classes of Altshuller and McBean (1979) (Percent of Waters in the Present Study Occurring in Each Shown in Parentheses)

Sensitivity	Alkalinity	Calcium	Conductivity	All three factors (% of total)
	(µeq/l)		(µS/cm)	
High	0-200 (48%)	0-200 (51%)	0-30 (9%)	(9%)
Moderate	200-400 (28%)	200-400 (22%)	31-70 (47%)	(3%)
Low	>400 (24%)	>400 (26%)	>70 (44%)	(16%)

Although the agreement between distributions of sensitive waters based on alkalinity and on calcium is fairly good, there is poor agreement between these distributions and that based on conductivity. A larger proportion of waters fall into the higher conductivity classes, probably due to the presence in many waters of elements such as chloride, sodium, and potassium that contribute to conductivity but not to acid neutralizing capacity. When the data are sorted in this way, only 9% of all waters meet all three criteria for high sensitivity, and only 3% meet all three criteria for moderate sensitivity. These percentages are much smaller than those of sensitivity determined by other criteria discussed earlier. The classes based on alkalinity and calcium, however, agree well with our earlier conclusions regarding sensitivity on the basis of alkalinity and calcite saturation index. As shown earlier, the calcite saturation index is highly correlated with alkalinity and also may serve as a predictor of sensitivity, but it is more complex and has no clear advantage other than to link pH and calcium with alkalinity.

Calcium-pH Model

Henriksen (1979) proposed a model involving the relationship between pH and calcium content. He derived an empirical curve for this relation: waters falling above the curve are classified as acidified (i.e., they have a lower pH than would be expected on the basis of their calcium content, due to depletion of their acid neutralizing capacity). When this curve is applied to our data (Figure 22) for waters with nonmarine calcium of 300 µeq/l or less, we find that 21 of 75 waters (28%) fall above the curve.

As pointed out by Haines and Akielaszek (1983), the relationship used by Henriksen presumes that nonmarine calcium content of surface waters is not affected by acidic deposition. Their linear regression of alkalinity against the sum of nonmarine calcium and magnesium was alkalinity = -53 + 0.93(Ca+Mg) ($R^2 = 0.948$), which agreed well with Henriksen's value of alkalinity = -14 + 0.93(Ca+Mg), except for a lower intercept. The corresponding regression equation for our data (Figure 14) is alkalinity = 76 + 0.42(Ca+Mg) ($R^2 = 0.409$, $p = 0.0001$), a higher intercept but a lower slope. The positive intercept for our data indicates that the calcium and magnesium ions were generally balanced by bicarbonate, and its magnitude is probably due to the larger proportion of other anions such as chloride in our waters.

In the New England study anions other than sulfate and bicarbonate appeared to be negligible as shown by ionic balance data which did not include chloride. Our ionic balance (Figure 12) indicates a substantial chloride component, but chloride probably does not enter importantly into buffering reactions.

Haines and Akielaszek (1983) presented a review of recent studies concerning the effect of acidic deposition on calcium and magnesium, or total cation, content of waters. Their evidence suggests that sulfate increases are balanced by equivalent bicarbonate decreases so long as bicarbonate is available, and that when bicarbonate is absent, sulfate increases are balanced by increases in cations such as aluminum, magnesium, and calcium. The lack of historical data on concentrations of these ions prevents us from testing this hypothesis directly. Figure 12 shows that of these ions, only aluminum seemed to increase in

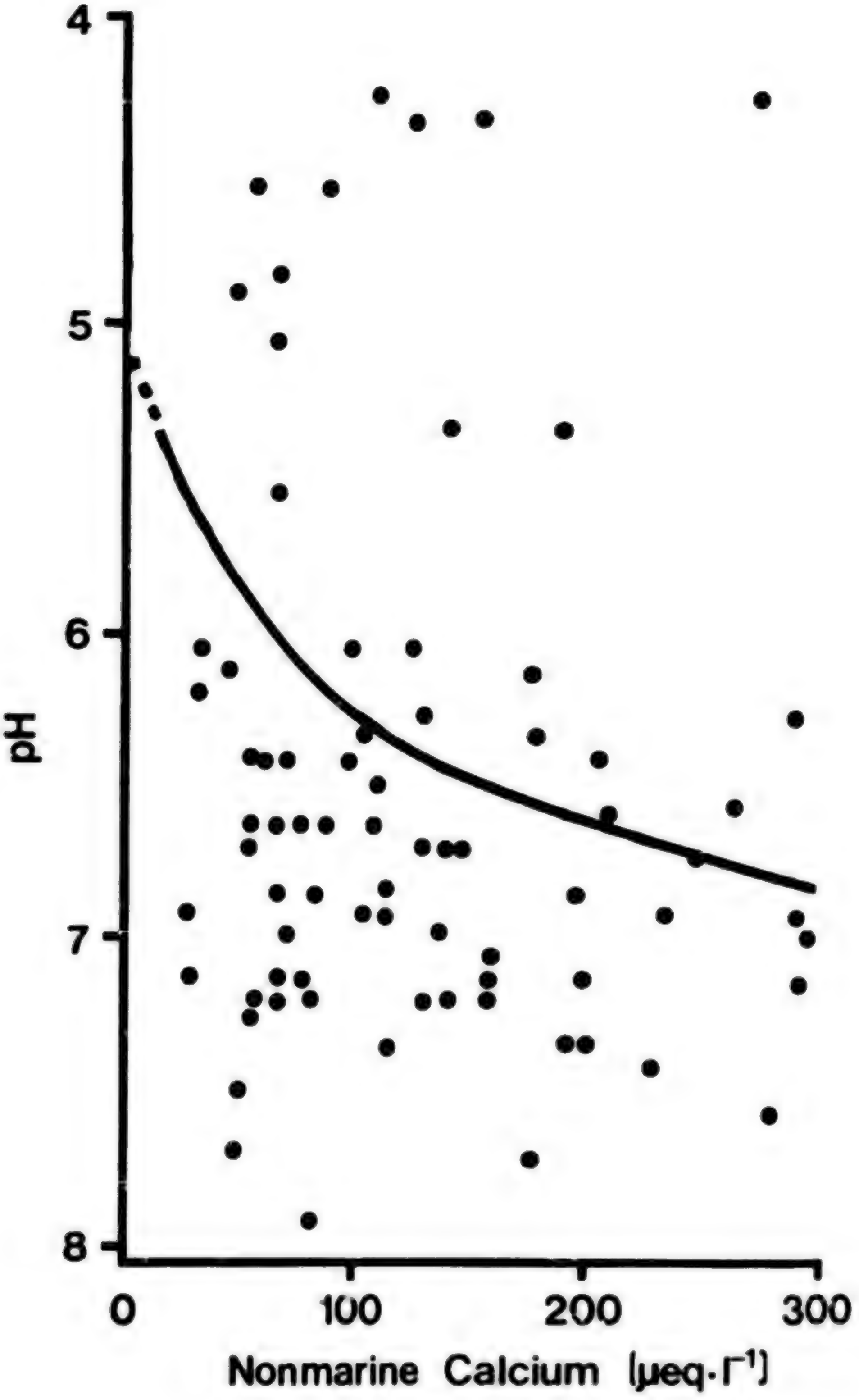

Figure 22. Calcium-pH model (Henriksen plot) applied to 75 Middle Atlantic States lakes having calcium concentrations less than 300 μeq/l. Waters falling above the curve are considered acidified.

concentration at low pH values where bicarbonate was absent. However, the data of Figure 12 are means, and trends in individual waters over time are obscured, especially considering the generally higher total ionic content of the higher pH waters.

Sulfate-pH Model

Henriksen (1979, 1980) also proposed that acidification could be related to the nonmarine sulfate content of surface waters. He constructed a nomograph relating pH to calcium plus magnesium and sulfate content of waters. We applied the regressions of this nomograph to our lake data and determined its success in predicting lake pH (Table 28, Figure 23). The predictive ability of the model was generally poor on data from the Middle Atlantic States, except for those lakes in the range of pH 4.7-5.3. The small number of our lakes in the "acidic" range makes it difficult to evaluate that part of the model.

Table 28. Prediction of pH of 82 Middle Atlantic Lakes Having Sums of Nonmarine Calcium Plus Magnesium Less than 500 µeq/l by Henriksen's Sulfate-pH Model

	pH range		
	<4.7	4.7-5.3	>5.3
Number actually in pH range	6	3	73
Number predicted to be in pH range	8	22	50
Number predicted correctly *	1	3	48
Percent predicted correctly *	17%	100%	66%

* i.e., portion of those actually in the pH range that fall within the predicted isopleths on the plot

Haines and Akielaszek (1983) performed a similar analysis and also reported poor predictive ability although the distribution of their results was somewhat different. They suggested that the poor predictive ability might be due to correlation of sulfate with pH in their data, or to an extraneous source of sulfate. They improved the model's predictive success somewhat by applying an arbitrary reduction factor to the sulfate

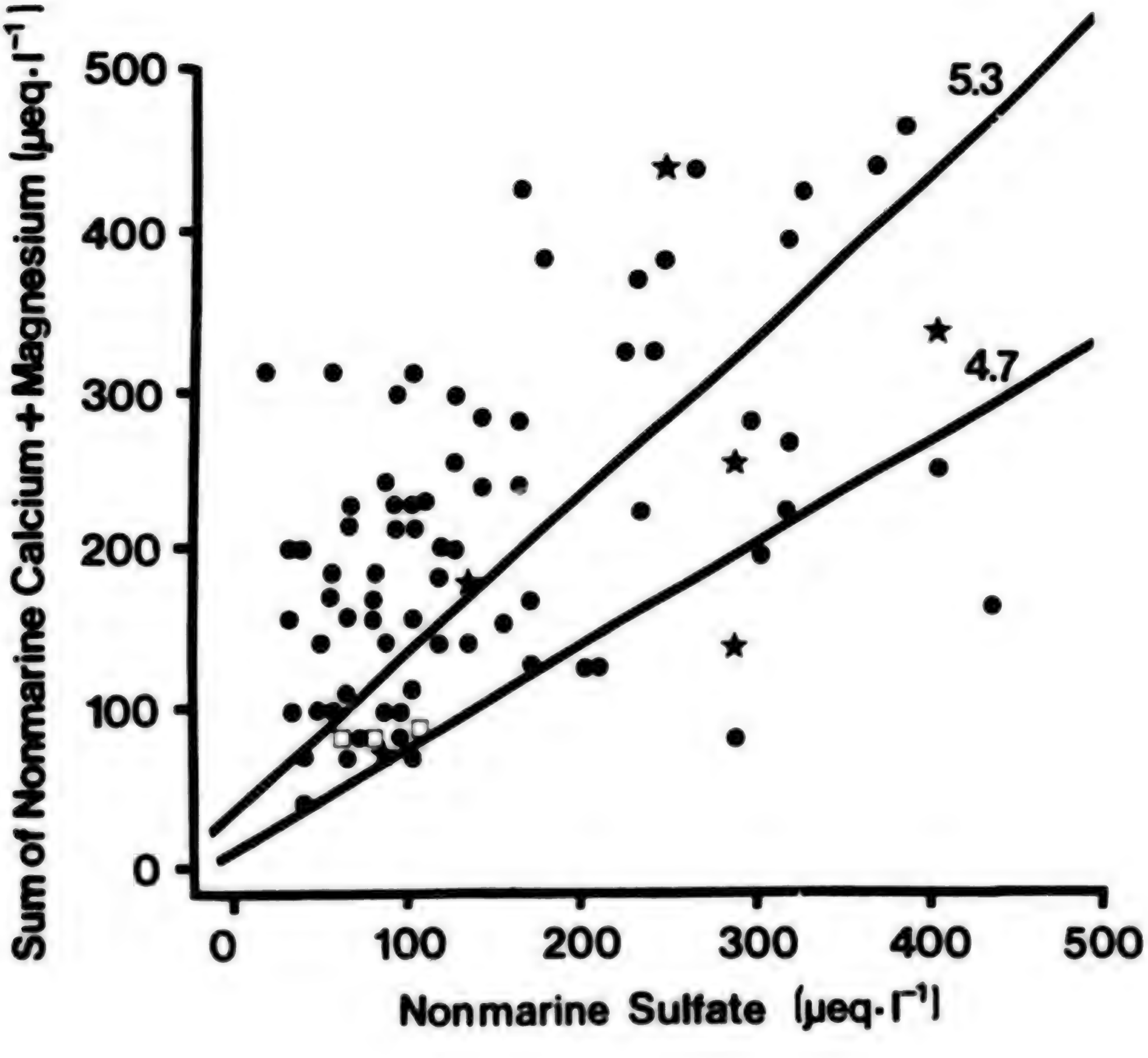

Figure 23. Sulfate-pH model (Henriksen nomograph) applied to 82 Middle Atlantic States lakes having calcium plus magnesium concentrations less than 500 μeq/l. Diagonal lines indicate Henriksen's (1980) regressions for waters of pH 4.6-4.8 ("4.7") and 5.2-5.4 ("5.3"). Symbols indicate pH of waters sampled in this study: ★ = pH < 4.7, □ = pH 4.7-5.3, ● = pH > 5.3.

values. We did not experiment with the model in this way because our sulfate data were not correlated with pH and because, as stated earlier, we found no evidence for a marine source of sulfate in our data. The use of the "nonmarine" correction for sulfate has already reduced our values below the actual measurements.

Cation Denudation Model

Thompson (1982) proposed a model of acidification based on the idea of "cation denudation" or the export of cations from a watershed in runoff. It is similar to the sulfate-pH model (Henriksen nomograph) except that the sum of cations is used rather than only calcium plus magnesium. With this model pH can be predicted from the carbonate buffering system of natural waters.

Table 29. Prediction of pH of 74 Middle Atlantic Waters Having Sums of Nonmarine Cations Less Than 600 µeq/l and Nonmarine Sulfate Less Than 500 µeq/l by Thompson's Cation Denudation Model

	pH range				
	4.0-5.0	5.1-6.2	6.3-6.5	6.6-6.8	>6.8
Number actually in pH range	7	10	9	11	37
Number predicted to be in pH range	2	14	30	15	11
Number predicted correctly *	0	2	5	4	8
Percent predicted correctly *	0	20	56	36	57

* i.e., portion of those actually in the pH range that fall in it on the plot

We examined our data using this model (Table 29, Figure 24) and compared predicted values with those observed for the actual

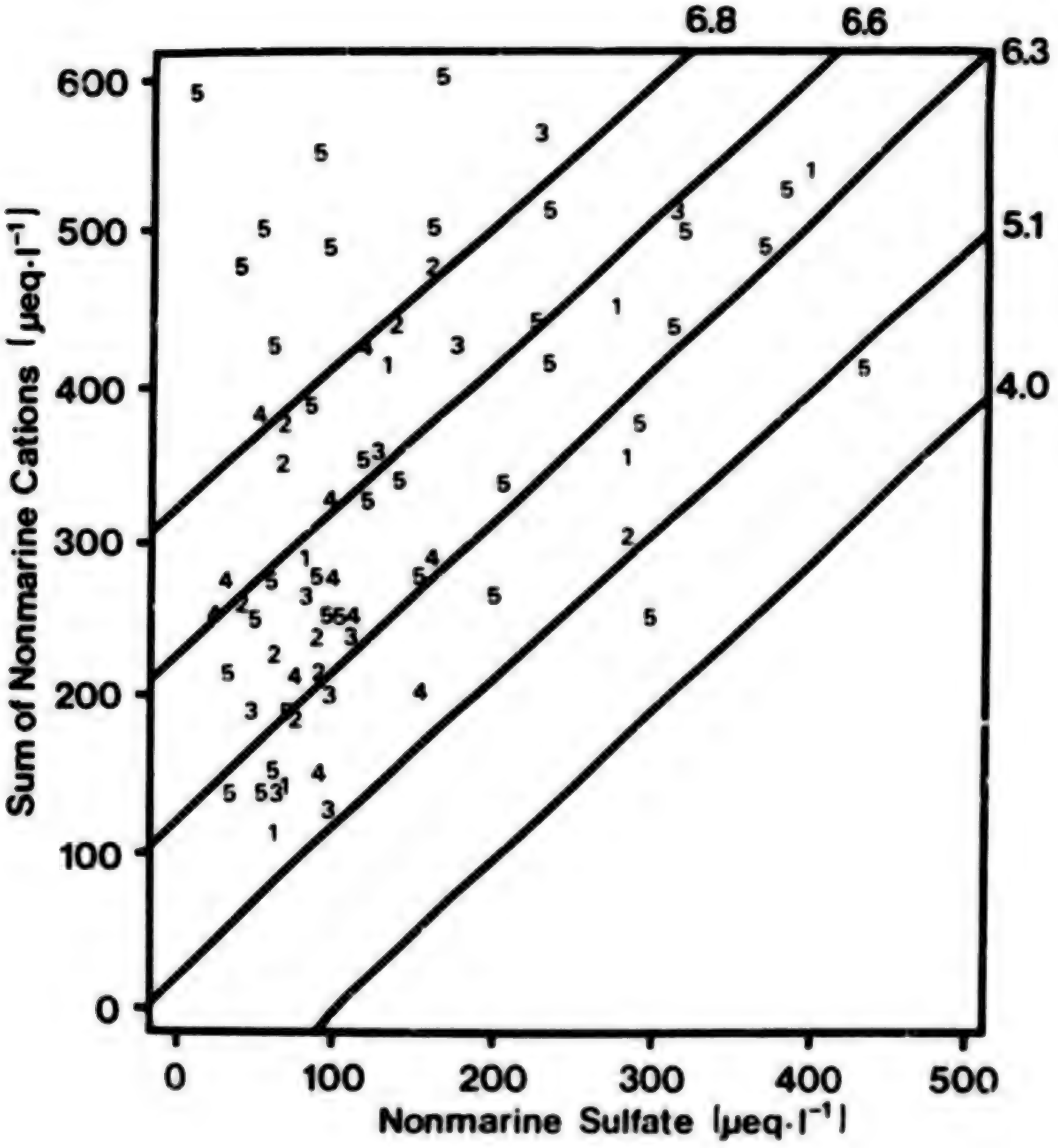

Figure 24. Thompson cation denudation model applied to 74 Middle Atlantic States waters with sums of cations and sulfate concentrations less than 600 μeq/l. Numbers indicate observed pH ranges (sample values averaged over depths and replicates): 1 = 4.0-5.0, 2 = 5.1-6.2, 3 = 6.3-6.5, 4 = 6.6-6.8, 5 = > 6.8.

samples. The predictive success was poor, ranging from 0-57%. In the New England study the fit to this model was good at lower pH values but deteriorated as pH of samples increased. This was not true of our data; in fact the agreement was better at higher pH values. There was no other obvious pattern to the agreement, and little improvement would be derived from reducing the sulfate values.

As pointed out by Haines and Akielaszek (1983) this model depends on the relationship between excess sulfate and acidification, as does the Henriksen pH-sulfate model. It can thus be used to predict pH changes for given sulfate loads if the relationship between sulfate in surface waters and sulfate in atmospheric deposition is known. Unfortunately this is not yet the case.

The cation denudation model can also be related to acidification which has already occurred. All points falling below the pH 5.1 line have other nonmarine cations in excess of bicarbonate; they may thus be classified as acidified. Of the 74 waters in our survey which are included in Figure 24, only 2 (3%) fall in the "acidified" category on this basis. This is considerably less than the 28% found by the calcium-pH model, and the 39% which decreased in pH based on historical data; or, of course, the 77% which decreased in alkalinity. Thus it appears that this model is not particularly useful for studying acidification in waters of the Middle Atlantic states.

CONCLUSIONS

1. About 45% of the unpolluted, relatively undeveloped waters sampled in the nine Middle Atlantic States are vulnerable to acidification on the basis of alkalinity being less than 200 µeq/l, or calcium content less than 200 µeq/l. Differences in water chemistry between lakes and streams, as groups, were small.

2. Alkalinity is probably the most useful and relatively accurate predictor of sensitivity to acidification. Calcite saturation index is also a valid predictor, but has no advantage over alkalinity.

3. Comparisons with historical data on the same waters indicated no significant overall change in pH but some decrease in the alkalinity of many waters. The accuracy of the historical data cannot be evaluated, however, so no firm conclusions regarding change can be drawn from it.

4. The calcium-pH plot of Henriksen is a fairly good predictor of lake pH values as related to calcium content. It predicted that about 28% of the sampled lakes were acidified.

5. Neither bedrock nor soil class is a particularly strong predictor of sensitivity to acidification. Bedrock class is somewhat related to alkalinity of Middle Atlantic States waters, but soil type is not, at least when determined from rock and soil maps presently available. Thus some published maps showing geographic areas which are sensitive to acid precipitation, but which are based on bedrock alone, may be misleading.

6. There was only one case of a potentially toxic aluminum/pH combination among the sampled waters.

RECOMMENDATIONS

The principal unanswered questions raised in this report could best be addressed by the collection of water chemistry data on a regularly repeated basis, at least once per season, from a selected group of the waters sampled for this study. Waters with low levels of calcium, alkalinity, and total ionic content should be emphasized. At least a majority of the waters should have data on their past water chemistry available, in addition to that collected for this study. Also, concurrent data on the status of fish populations and their food chains in the same waters should be collected in order to document the effect, or lack thereof, of observed water chemistry trends on the aquatic ecosystem.

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APPENDIX A. DATA OF THIS STUDY

Data in the head block for each station are arranged as follows by line (see text for details):

1. station number - water body name - county - state
2. latitude (degrees, minutes, seconds) - longitude - USGS 7.5-minute quadrangle name - elevation (m)
3. date of sample (year, month, day) - Secchi disc transparency (m) (lakes only, streams = ***) - approximate area (ha) of pond/lake, or width (m) of stream - bedrock class (see Table 1) - soil class (see Table 1)
4. disturbance code (see Table 2) - annual mean pH of precipitation at site - mean annual amount of precipitation at site (mm)

The labeled columns are as follows:

D	depth of sample (m)
T	temperature at sample depth (°C)
FLD PH	pH measured in the field
LAB PH	pH measured in the laboratory
FEP ALK	fixed endpoint alkalinity as calcium carbonate (µeq/l)
DEP ALK	double endpoint alkalinity as calcium carbonate (µeq/l)
COND	conductivity in µS/cm
Al	aluminum (total) in µeq/l
Ca	calcium in µeq/l
Cl	chloride in µeq/l
CLR	color in Pt-Co units
K	potassium in µeq/l
Mg	magnesium in µeq/l
Mn	manganese in µeq/l
Na	sodium in µeq/l
SO_4	sulfate in µeq/l

In most cases where there are samples listed from two depths, the second depth is the near-bottom sample taken near the deepest part of the lake or pond. (In a few cases our sampling equipment would not reach bottom; these were generally over 30 m deep and the second sample was taken at the maximum depth possible but not necessarily near the bottom).

```
                                                  FLD  LAB   FEP    DEP
                                          D   T   pH   pH    ALK    ALK  COND   Al    Ca    Cl CLR    K     Mg  Mn   Na    SO4

2101 CAYUTA LAKE          SCHUYLER   NY
     422127 764434 ALPINE            402m
     81/ 3/ 3  1.5m  148ha  BR2 S5
     DIST4  RAINpH: 4.1   864mm
                                          0   0  7.2  7.33   745    696   200   24   764   688   8   108    279 0.0 235   391
                                          2   0  7.2  7.59  1455   1401   215   30  1123   417   8    94    499 0.0 160   426

2102 GREEN VALLEY LAKE    SCHUYLER   NY
     422440 770320 WAYNE             381m
     81/ 3/ 3  1.5m   30ha  BR2 S5
     DIST4  RAINpH: 4.1   313mm
                                          0   0  7.3  8.26   416    380   117   29   521   311   8    39    223 0.0 165   260
                                          2   0  7.2  8.44   457    421   118   43   709   298   8    61    458 0.0 115   273

2103 CUNNINGHAM CREEK     STEUBEN    NY
     421926 773550 CANISTEO          470m
     81/ 3/ 3  ***m    4m   BR2 S5
     DIST3  RAINpH: 4.1   864mm
                                          0   0  7.5  8.84   674    629   170   36  1250   292   4    77    674 0.0 133   519

2104 CASE LAKE            CATTARAUGU NY
     421857 782358 FRANKLINVILLE     534m
     81/ 3/ 3  ***m   25ha  BR2 S4
     DIST3  RAINpH: 4.1  1067mm
                                          0   0  7.7  7.09   319    291    76   26   445   123   1    93    177 0.0 185   325

2105 BEEHUNTER CREEK      CATTARAUGA NY
     420559 784420 LIMESTONE         432m
     81/ 3/ 4  ***m    7m   BR2 S5
     DIST3  RAINpH: 4.1  1067mm
                                          0   0  6.9  7.40   167    140    52   38   322    33   3    59    176 0.0 131   182

2106 UNNAMED POND         STEUBEN    NY
     421156 771634 RATHBONE          411m
     81/ 6/29  1.7m    8ha  BR2 S5
     DIST3  RAINpH: 4.1   864mm
                                          0  22  8.6  9.29   628    587   125    3   654   303   8    12    214 1.3  18   163
                                          2  21  9.2  9.41   633    574   125    3   663   298   8    13    228 1.9  19   163

2107 FOSTER LAKE          ALLEGANY   NY
     421355 774343 ANDOVER           689m
     81/ 6/29  1.3m   12ha  BR2 S5
     DIST3  RAINpH: 4.1   914mm
                                          0  22  7.0  7.71   181    149    49    6   271    34   4    17    122 2.0  15   184
                                          2  21  6.7  7.44   176    145    50    6   273    32   4    17    124 2.0  14   183

2108 FAULKNER POND        ALLEGANY   NY
     420746 790730 BOLIVAR           701m
     81/ 6/29  0.5m    1ha  BR2 S5
     DIST2  RAINpH: 4.1   914mm
                                          0  23  7.2  7.11    63     31    34    5   154    31   3    16     65 4.4   7   111
                                          3  21  7.3  7.26    72     49    36    6   162     2   3    16     67 7.2   7   106
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```
                                                   FLD  LAB   FEP    DEP
                                          D   T    pH   pH    ALK    ALK   COND   Al     Ca     Cl  CLR    K      Mg   Mn    Na    SO4

2109 KEYSER RESERVOIR     CATTARAUGU NY
     420640 785739 STEAMBURG       503m
     81/ 6/29  1.5m    14ha  BR2 SS
     DIST3  RAINpH: 4.1  1118mm
                                          0  24   6.6  7.01  172    145    45    23     79     29    4    33     67  1.7   15    127
                                          7  10   6.3  6.69  349    321    62    50    120     39    4    46    145 40.3   46    127

2110 SAUNDERS POND        ALLEGANY   NY
     421338 775815 WELLSVILLE NOR 533m
     81/ 6/29  0.5m     6ha  BR2 SS
     DIST3  RAINpH: 4.1   914mm
                                          0  23   9.0  9.24  851    801   135    11    617     39   10    22    356  9.5   57    148
                                          1  22   9.0  8.56  878    846   139    12    590     47   10    23    367 10.8   57    153

2111 CLEAR LAKE           ERIE       NY
     423312 785108 LANGFORD        369m
     81/ 3/ 4  0.9m    19ha  BR2 SS
     DIST2  RAINpH: 4.1  1316mm
                                          0   0   7.1  7.37  407    375   131    48    755    234   11    60    535  0.0  133    303
                                          2   0   7.2  7.21  556    525   141    37    612    279   12    72    331  0.0  134    248

2117 HEMLOCK LAKE         LIVINGSTON NY
     424600 773700 HONEOYE FALLS   276m
     81/ 6/14  2.5m   684ha  BR2 SS
     DIST2  RAINpH: 4.1   813mm
                                          0  21   8.5  8.17  958    918   196     7   1123    414    3    17    520  0.4   61    361
                                         15  12   7.5  7.83 1090   1050   203     8   1050    422    3    20    525  0.5   72    390

2120 DUCK LAKE            CAYUGA     NY
     430855 764120 VICTORY         121m
     81/ 6/14  1.3m    86ha  BR4 SS
     DIST4  RAINpH: 4.1   914mm
                                          0  23   8.5  8.33 2022   1991   249    10   1886    345    4    21   1065  0.9  159    204
                                          2  21   8.5  7.72 2023   1968   246     9   2163    335    7    29   1145  1.4  158    208

2121 SILVER LAKE          OSWEGO     NY
     432240 763300 OSWEGO WEST     106m
     81/ 6/14  ***m    37ha  BR2 SS
     DIST3  RAINpH: 4.1   914mm
                                          0  21   7.5  8.31  729    656    85     9    242     39    9    20    127  0.9   18     72

2123 CHASE POND           OSWEGO     NY
     432112 755912 PANTHER LAKE    172m
     81/ 3/ 4  ***m    23ha  BR3 SS
     DIST3  RAINpH: 4.2  1270mm
                                          0   0   6.0  5.87  108     69    31    34    586     19   18    66    280  0.0  184    148

2124 ECHO LAKE            ONEIDA     NY
     432539 751556 BOONEVILLE      397m
     81/ 3/ 5  2.7m    37ha  BR4 SS
     DIST4  RAINpH: 4.2  1321mm
                                          0   0   6.6  7.22  389    351    52    30    445      9    1    93    195  0.0  163     72
                                          3   2   6.5  7.19 1216   1170   126    31    477     11    1    81    226  0.0  156    203
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                                                       FLD   LAB    FEP    DEP
                                               D   I   pH    pH     ALK    ALK  COND   Al    Ca     Cl CLR     K     Mg  Mn   Na    SO4
2125 CATSPAW LAKE          LEWIS      NY
     434217 751733 BRANTINGHAM    361m
     81/ 3/ 5  1.5m   18ha  8B1 S3
     DIST3  RAINpH: 4.2  1321mm
                                               0   0  4.8   4.79     4    -10    14    31   406     3   8    82    189 0.0 157    46
                                               2   3  4.8   5.33    37      9    15    31   496     4   4    81    236 0.0 152    57

2126 SEARS POND            LEWIS      NY
     434425 754253 SEARS POND     529m
     81/ 3/ 5  ***m   34ha  8B2 S5
     DIST3  RAINpH: 4.2  1219mm
                                               0   0  6.3   7.32   233    221    37    34   633     7  25    70    357 0.0 132    74

2128 ASHCRAFT POND OUTLET LEWIS       NY
     443156 752808 NATURAL BRIDGE 262m
     81/ 3/ 5  ***m   16m   9B1 S5
     DIST1  RAINpH: 4.2  1016mm
                                               0   1  5.6   6.55   136    104    32    50   981    13  25    45    733 0.0  98   208

2129 LAKE OF THE WOODS     JEFFERSON  NY
     441930 754333 MUSKELLUNGE LA 100m
     81/ 6/11  5.5m   72ha  8B4 S5
     DIST2  RAINpH: 4.2   914mm
                                               0   2  6.6   9.13   679    634    85     4   493    53   3    14    177 0.0  17   127
                                              22  10  7.1   7.53   554    519   133     4   487    60   3    13    178 0.5  17   132

2131 TROUT BROOK           ST LAWRENC NY
     441956 744753 PARISHVILLE    215m
     81/ 3/ 5  ***m    3m   8B2 S4
     DIST3  RAINpH: 4.2   914mm
                                               0   0  7.3   8.53   518    481    84    28   395    55   3    55    161 0.0 175   288

2132 LAKE DUANE OUTLET     FRANKLIN   NY
     444128 741854 LAKE TITUS     457m
     81/ 3/ 6  ***m    2m   8B1 S3
     DIST1  RAINpH: 4.3   914mm
                                               0   0  5.3   6.81   126     99    54    48   811   113   3    54    533 0.0 112   101

2134 SILVER LAKE           CLINTON    NY
     443045 735153 REDFORD        425m
     81/ 3/ 6  2.1m  325ha  8B1 S3
     DIST4  RAINpH: 4.3   914mm
                                               0   0  6.0   7.23   189    161    35    27   368    10   3   101    146 0.0 182   216
                                               2   0  6.0   7.17   153    125    39    29   427    13   4    79    182 0.0 168   216

2135 NEWPORT POND          ESSEX      NY
     442448 733545 WITHERBEE      118m
     81/ 3/ 6  1.5m    9ha  8B2 S5
     DIST2  RAINpH: 4.3   914mm
                                               0   0  5.2   6.41    95     76    39    31   467    47  20    72    218 0.0 157    84
                                               4   2  5.5   6.49   217    190    53    37   659   134  15    66    368 0.0 129    78
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                                                   FLD   LAB   FEP   DEP
                                          D    T   pH    pH    ALK   ALK  COND   Al    Ca    Cl CLR    K    Mg  Mn   Na    SO4
2137 CRYSTAL LAKE          WARREN      NY
     433918 734435 BRANT LAKE      291m
     81/ 3/ 6  1.5m   23ha  BR1 S3
     DIST4  RAINpH: 4.3   914mm
                                          0    0   6.0  6.81   185   149   47    38   645    81   9   72   355 0.0 131    94
                                          9    2   5.7  7.26   317   276   58    34   558    73   5   82   277 0.0 145    89

2138 BUTLER POND           WARREN      NY
     432152 734357 GLENS FALLS     317m
     81/ 3/ 6  ***m   36ha  BR2 S2
     DIST1  RAINpH: 4.3  1067mm
                                          0    2   5.5  6.73   137    93   36    25   326    39   3   89   122 0.0 191   265

2140 DUCK POND             FRANKLIN    NY
     443603 740840 DeBAR MOUNTAIN 502m
     81/ 3/ 6  0.9m   26ha  BR1 S3
     DIST2  RAINpH: 4.3   914mm
                                          0    0   4.9  5.15    28     0   13    31   491     0   4   79   230 0.0 153    35
                                          2    2   4.7  5.17    32     5   20    31   473     2   9   85   221 0.0 157   127

2141 KING PHILLIPS SPRING ESSEX        NY
     440435 733989 WITHERBEE       305m
     81/ 3/ 6  ***m    1m   BR2 S5
     DIST0  RAINpH: 4.3   914mm
                                          0    4   5.2  6.31   149   136   31     0   156     5   3    8    32 0.0   1    62

2143 BALFOUR LAKE          ESSEX       NY
     445132 740030 NEWCOMB 15'     545m
     81/ 3/ 6  2.1m   38ha  BR2 S3
     DIST3  RAINpH: 4.3   914mm
                                          0    0   5.4  5.82    63    36   45    40   683   229   9   65   398 0.0 126    67
                                          2    1   5.5  6.28    81    49   72    40   698   464  11   56   408 0.0 123    72

2144 TRIB TO SPRUCE CREEK HERKIMER     NY
     431322 744842 SALISBURY       476m
     81/ 3/ 7  ***m    5m   BR2 S5
     DIST2  RAINpH: 4.2  1219mm
                                          0    1   5.5  4.33     0    -9   30    89  2035     5   9   29  2650 9.3  54    72

2146 CATAMOUNT POND        FRANKLIN    NY
     441548 743800 CHILDWOLD       463m
     81/ 6/12  1.5m   42ha  BR2 S3
     DIST2  RAINpH: 4.2  1016mm
                                          0   20   7.3  6.73   112    63   41     7   134   123  25   18    63 0.6   8   100
                                          3   18   7.3  6.67    80    45   35     7   129    84  25   18    63 0.9   8    89

2147 ROCK LAKE             HAMILTON    NY
     434958 742000 BLUE MOUNTAIN  520m
     81/ 6/13  2.0m   75ha  BR1 S5
     DIST1  RAINpH: 4.3   914mm
                                          0   19   7.0  7.03   127    36   38     8    31    87  15   18    16 0.7   2    72
                                          4   18   6.9  7.20   122   100   41    15    92    63  20   25    62 0.5  11    62
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                                                    FLD  LAB   FEP    DEP
                                           D   T    pH   pH    ALK    ALK   COND  Al     Ca     Cl CLR     K      Mg  Mn    Na    SO4
2148 'G' LAKE              HAMILTON    NY
     432500 743800 PISECO LAK 15' 619m
     81/ 6/13  2.5m   36ha  BR2 S3
     DIST1  RAINpH: 4.3  1321mm
                                           0  20   5.5  5.59    36      9    22    0    339      5   3      3      31  1.8    0     62
                                           6  13   6.2  5.19    31     13    24    8     33      5   4     19      16  1.3    2     67

2149 KECKS CENTER CREEK   FULTON       NY
     430240 742707 PECK LAKE         325m
     81/ 6/13  ***m     1m   BR4 S2
     DIST1  RAINpH: 4.3  1016mm
                                           0  18   7.4  7.68  1027    991   118    0    811     31   5     10     217  0.0   14     78

2151 BOND LAKE             NIAGARA     NY
     431048 785500 RANSOMVILLE      167m
     81/ 6/15  3.0m   13ha  BR2 S5
     DIST3  RAINpH: 4.1   864mm
                                           0  25   8.7  9.08  1240   1204   187   45    832    443   6     44     901  0.7  287    120
                                           2  22   8.8  9.27  1509   1339   187   39    861    517   4     41     913  1.3  258    137

2152 DARIEN LAKE           GENESEE     NY
     425435 782700 CORFU             271m
     81/ 6/15  3.0m   20ha  BR4 S5
     DIST4  RAINpH: 4.1   864mm
                                           0  22   7.9  7.58  1614   1475   550    0    780   4249   4     10     216  0.4   16    295
                                           3  22   7.9  7.55  1512   1388   578    0   1731   4072  15      6     417  0.9   26    321

2190 SKY LAKE              BROOME      NY
     420452 753253 GULF SUMMIT      524m
     81/ 7/23  1.5m   12ha  BR2 S5
     DIST3  RAINpH: 4.2  1067mm
                                           0  25   6.4  7.28   203    139    34   14    136     34   7     25      90  3.2   15     67
                                           3  23   6.3  7.20   189    130    39   13    142     36  10     24      85  3.7   14     72

2191 CRYSTAL LAKE          SULLIVAN    NY
     413646 745442 ELDRED            387m
     81/ 7/23  2.3m   61ha  BR2 S5
     DIST3  RAINpH: 4.3  1118mm
                                           0  25   5.9  6.63    69     23    41    9    132    100  10     20      69  0.9    9    148
                                           6  12   5.6  6.11   157    102    40   10    125     79  11     22      70 13.8   10    101

2192 GUYMARD LAKE          ORANGE      NY
     412555 743555 OTISVILLE         217m
     81/ 7/23  1.7m   13ha  BR2 S5
     DIST3  RAINpH: 4.3  1118mm
                                           0  26   6.3  7.47   183    125    79   19    203    219   5     28     148  3.3   30    273
                                           3  25   6.3  7.24   204    143    61   22    184    142   7     32     150  3.6   32    249
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                                                 FLD   LAB    FEP    DEP
                                        D   T    pH    pH     ALK    ALK   COND   Al     Ca     Cl  CLR    K     Mg   Mn    Na    SO4
2193 KLEINE KILL LAKE     ULSTER      NY
     414502 740631 MOHONK LAKE    171m
     81/ 7/23  1.0m     2ha  BR2 S3
     DIST1  RAINpH: 4.3  1118mm
                                        0  23   7.1   7.77   759    689   100    29    428     36   7     35    403  2.1   98    327
                                        3  18   6.8   7.76   920    860   122    30    433     68   9     37    425 20.3  107    244

2194 NORTH LAKE           GREENE      NY
     421102 740229 KAATERSKILL    650m
     81/ 7/22  1.0m    16ha  BR2 S5
     DIST4  RAINpH: 4.3  1118mm
                                        0  23   6.5   6.45   120     69    29     8    110     31  18     19     55  2.4    7    106
                                        2  23   6.6   6.99   144     88    35     9    108     73  19     20     54  2.5    7    223

2195 ALDER LAKE           ULSTER      NY
     420259 744051 ARENA          674m
     81/ 7/22  1.5m    16ha  BR2 S5
     DIST2  RAINpH: 4.3  1168mm
                                        0  23   7.6   7.57   259    213    40     0    253      7   6      9     65  1.2    4     89
                                        4  17   6.4   6.47   287    245    67     0    242     26   6     10     66  4.9    4    111

2196 SUNHILL POND         DELAWARE    NY
     422730 745350 DAVENPORT      503m
     81/ 7/22  2.0m     1ha  BR2 S5
     DIST4  RAINpH: 4.3  1067mm
                                        0  23   6.6   7.35   282    236    42    11    192     10   7     22    110  2.9   17    122

2197 TUNIS LAKE           DELAWARE    NY
     421356 744649 ANDES          608m
     81/ 7/22  1.0m     7ha  BR2 S5
     DIST3  RAINpH: 4.3  1092mm
                                        0  24   8.2   8.36   294    251    45    15    191     29   7     26    129  1.5   24    494
                                        2  23   8.6   9.03   296    231    53    14    200    113   6     25    129  1.7   23    528

2198 SEXSMITH LAKE        DELAWARE    NY
     422754 744941 DAVENPORT      564m
     81/ 7/22  2.0m    13ha  BR2 S5
     DIST3  RAINpH: 4.3  1067mm
                                        0  24   6.6   7.24   129     87    37    12    130    113   8     24     81  1.7   13    284
                                        3  24   6.3   7.13   106     55    31    13    131     21   7     23     81  1.8   13    340

2199 TRIB TO ELM CREEK    ST LAWRENC NY
     442030 751256 EDWARDS        225m
     81/ 6/12  ***m     2m   BR3 S3
     DIST2  RAINpH: 4.2  1016mm
                                        0  14   8.1   8.62   606    606    79    23    305     26  25     31    251  0.0   54     67

2201 LAKE GENEVIEVE       WARREN      NJ
     405937 745802 BLAIRSTOWN     125m
     81/ 1/29  1.5m     8ha  BR4 S3
     DIST4  RAINpH: 4.3  1219mm
                                        0   0   7.3   7.24  2349   2261   230    31    922    514   3     87    432  0.8  154    577
                                        1   4   7.4   7.43  2571   2520   338    37    846    543   4     77    454  0.9  135    564
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                                                  FLD  LAB   FEP   DEP
                                         D   T    pH   pH    ALK   ALK  COND  Al    Ca    Cl CLR    K    Mg   Mn   Na    SO4
2202 FAIRVIEW LAKE         SUSSEX     NJ
     410437 745445 FLATBROOKVILLE 278m
     81/ 1/29  2.1m   43ha  BR2 S4
     DIST3  RAINpH: 4.3  1168mm
                                         0   0   6.0  6.95   250   245   90   31   427   298   5    90   201  1.7 158   377
                                         3   4   6.2  6.55   194   175   85   36   436   237   4    74   228  1.7 136   349

2203 ASHROE LAKE           SUSSEX     NJ
     411050 744855 CULVERS GAP    241m
     81/ 1/29  2.1m   13ha  BR2 S5
     DIST3  RAINpH: 4.3  1143mm
                                         0   0   6.4  6.83   352   321   69   34   583    57   0    73   294  3.5 142   292
                                         2   5   6.5  6.60   402   365   27   36   687    29   1    59   375  3.2 132   292

2204 STEENYKILL LAKE       SUSSEX     NJ
     411907 744034 PORT JERVIS SO 406m
     81/ 1/29  2.4m    4ha  BR2 S4
     DIST4  RAINpH: 4.3  1118mm
                                         0   0   5.9  6.60   194   162  154   33   366   831   0    71   178  2.5 149   387
                                         3   4   6.1  6.17   222   176  174   34   445   831   3    75   222  2.5 144   390

2205 LAKE LOOKOUT          SUSSEX     NJ
     410930 742335 WAWAYANDA      363m
     81/ 1/30  1.2m    5ha  BR2 S4
     DIST0  RAINpH: 4.3  1168mm
                                         0   0   5.6  5.99   125    97   87   53   762    55   5    49   587 25.6  93   662
                                         1   4   5.6  6.03   171   134   88   48  1038    70   7    53   731 28.6 102   662

2206 STEPHENS LAKE         PASSAIC    NJ
     410315 741605 WANAQUE        125m
     81/ 1/30  1.2m    3ha  BR1 S3
     DIST4  RAINpH: 4.3  1168mm
                                         0   0   6.9  6.20   162   125  222   54  1001    89  10    50   788 11.1  93  2126
                                         1   6   6.3  6.27   152   106  236   55   936   174  10    52   766 10.3  89  2275

2207 SURPRISE LAKE         MORRIS     NJ
     405714 742118 POMPTON PLAINS 198m
     81/ 1/30  1.2m    7ha  BR1 S3
     DIST3  RAINpH: 4.3  1194mm
                                         0   0   7.1  7.43   490   472   99   31   471   176   4    73   218  1.7 157   361
                                         2   5   6.8  7.23   537   703  102   33   513   285   3    69   249  1.2 150   364

2208 MOUNT HOPE POND       MORRIS     NJ
     405547 743255 DOVER          259m
     81/ 1/30  2.1m    3ha  BR1 S4
     DIST4  RAINpH: 4.3  1219mm
                                         0   0   6.8  6.96   241   213  115   34   226   483   0    64   115  2.6 140   370
                                         3   5   6.8  6.07   157   144   85   43   361   393   0    53   224  2.6 115   398

2209 SUNSET LAKE           SUSSEX     NJ
     410150 743640 FRANKLIN       326m
     81/ 1/30  1.2m    4ha  BR1 S4
     DIST3  RAINpH: 4.3  1194mm
                                         0   0   6.6  6.95   823   787  100   24   616    55   1    90   218  8.6 202   516
                                         2   4   6.6  5.76   827   791  140   41   969    44   5    69   599 18.1 117   523
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                                                     FLD  LAB   FEP    DEP
                                          D    T     pH   pH    ALK    ALK   COND   Al     Ca     Cl  CLR     K      Mg   Mn    Na    SO4
2210 MOUNTAIN LAKE         WARREN      NJ
     405130 745910 WASHINGTON       125m
     81/ 1/30  1.5m   42ha  BB4 S5
     DIST4  RAINpH: 4.3  1219mm
                                          0    0    7.6  7.36 1341   1217   209   21    819    155    6   134    256  1.7 231    490
                                          1    4    7.4  8.59 1757   1716   223   38    518    161    4    66    289  3.4 127    509

2211 LAKE SOLITUDE         HUNTERDON   NJ
     404026 745315 HIGH BRIDGE       87m
     81/ 1/30  2.0m    7ha  BB1 S5
     DIST4  RAINpH: 4.3  1219mm
                                          0    0    7.5  8.39 1452   1383   228   16    625    380    4   169    153  0.8 300    344
                                          2    1    7.3  8.37 1507   1480   212   30    492    385    8    85    223  0.8 160    326

2212 ALEXAUKEN CREEK DAM  HUNTERDON   NJ
     402422 745430 STOCKTON          50m
     81/ 1/31  1.2m    6ha  BB2 S5
     DIST4  RAINpH: 4.3  1219mm
                                          0    0    6.8  6.43  670    650   131   34    916    263    8    65    469 13.6 143    402
                                          3    3    6.3  6.90  629    589    99   45   1147    192    3    55    765 13.6 108    415

2213 HARIHOKAKE CREEK      HUNTERDON   NJ
     403244 750407 FRENCHTOWN        35m
     81/ 1/31  ***m    4m   BB2 S5
     DIST4  RAINpH: 4.3  1219mm
                                          0    0    7.2  6.92  814    749   168   30    538    435    0    76    236  0.8 165    476

2214 SIX MILE RUN          SOMERSET    NJ
     402812 743232 MONMOUTH JUNCT    17m
     81/ 2/12  ***m    6m   BB2 S3
     DIST4  RAINpH: 4.3  1219mm
                                          0    0    6.9  6.92  347    329   230   52    244    630   10    48    190  7.7  93    654

2215 ROCK RUN POND         SOMERSET    NJ
     402440 744153 ROCKY HILL        27m
     81/ 2/12  0.3m    4ha  BB2 S4
     DIST4  RAINpH: 4.3  1219mm
                                          0    0    6.6  7.10  217    185   120   69    252    365   40    33    259  6.0  71    528
                                          2    0    6.4  6.44  231    199   116   79    383    369   40    33    449  6.8  61    511

2216 PERRINEVILLE LAKE     MONMOUTH    NJ
     401333 742610 ROOSEVELT         50m
     81/ 2/12  0.6m    6ha  BB2 S5
     DIST4  RAINpH: 4.3  1168mm
                                          0    3    6.3  6.26   46      0   111   63    532    393    1    45    506  4.3  77    236

2217 RED VALLEY LAKE       MONMOUTH    NJ
     400946 742835 ROOSEVELT         41m
     81/ 2/12  ***m    7ha  BB2 S5
     DIST4  RAINpH: 4.3  1168mm
                                          1    0    6.3  5.36  171    145    92   86    182    414    3    30    229 12.8  57    288
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                                                       FLD  LAB   FEP   DEP
                                            D    I     pH   pH    ALK   ALK   COND  Al    Ca    Cl  CLR    K    Mg  Mn   Na   SO4
2218 JACKSON'S MILLS LAKE OCEAN       NJ
     400859 741932 ADELPHIA         29m
     81/ 2/12  0.6m    8ha  BB2 S3
     DIST4  RAINpH: 4.3  1168mm
                                            0    0    4.7  4.28   -20   -14    74  128   134   153  12    17   253 5.2  38   415
                                            1    0    4.7  4.31   -13   -18    75  171    88   158  15    16   227 6.0  28   424

2219 BRISBANE LAKE          MONMOUTH   NJ
     400940 740725 ASBURY PARK      23m
     81/ 2/11  0.4m    5ha  BB2 S3
     DIST4  RAINpH: 4.3  1168mm
                                            0    0    5.1  5.64    32     0    49   51   155   205   6    54   116 3.4  97   182
                                            2    4    5.8  5.15    32     5    71   98   138   351   6    26   201 6.0  50   225

2220 SUCCESS LAKE           OCEAN      NJ
     400330 742342 CASSVILLE        29m
     81/ 2/13  1.2m   15ha  BB2 S5
     DIST2  RAINpH: 4.3  1118mm
                                            0    1    4.1  4.34   -11   -11    55  ***  ****   110  20  ****  **** *** ***   297
                                            1    2    4.4  4.38   -12   -12    55   49   153   100  19    48   110 1.7 101   295

2221 BAMBER LAKE            OCEAN      NJ
     395316 741909 KESWICK GROVE    23m
     81/ 2/13  ***m   24ha  BB2 S4
     DIST4  RAINpH: 4.3  1118mm
                                            0    2    4.1  5.39    23     0    25   31    62   110   9    87    28 1.7 156    89

2222 CRANBERRY BOG RESERV OCEAN       NJ
     395510 742726 WHITING          38m
     81/ 2/13  ***m   16ha  BB2 S3
     DIST1  RAINpH: 4.3  1118mm
                                            0    1    4.2  4.30     0   -15    48   46   268   113   8    50   184 1.7 195   265

2223 OYSTER CREEK           OCEAN      NJ
     394755 741502 BROOKVILLE       17m
     81/ 2/13  ***m    5m   BB2 S3
     DIST3  RAINpH: 4.3  1119mm
                                            0    4    4.5  4.42    -6   -29    47   32   440   174   6    70   213 0.8 152   132

2224 DECOY POND             BURLINGTON NJ
     394855 742715 WOODMANSIE       35m
     81/ 2/13  ***m    2ha  BB2 S4
     DIST0  RAINpH: 4.3  1118mm
                                            0    4    4.9  6.47    13     0    12   33   412   330  15    77   204 1.7 149   117

2225 OSWEGO LAKE            BURLINGTON NJ
     394355 742923 OSWEGO LAKE      16m
     81/ 2/13  ***m   36ha  BB2 S4
     DIST3  RAINpH: 4.3  1118mm
                                            0    2    5.0  4.35     0     0    46   34   123   102   3    65    62 0.0 141   148
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                                                 FLD  LAB   FEP   DEP
                                        D   T    pH   pH    ALK   ALK  COND  Al    Ca    Cl  CLR    K     Mg  Mn   Na   SO4

2226 ATSION LAKE          BURLINGTON NJ
     394429 744411 ATSION            15m
     81/ 2/13  2.2m   43ha  BR2 S5
     DIST4  RAINpH: 4.3  1118mm
                                        0   2   4.5  4.57   29    10    45   54   111    95    4    50    88  0.0  89   309
                                        2   3   4.3  4.54    9   -19    59   40    64    75    3    67    37  0.0 123   282

2227 PARVIN LAKE          SALEM      NJ
     393103 753839 ELMER             20m
     81/ 2/14  0.9m   37ha  BR2 S5
     DIST4  RAINpH: 4.3  1118mm
                                        1   3   6.8  6.75  167   136    90   42   326   329    3    63   201  0.0 116   325

2228 ELK LAKE             CUMBERLAND NJ
     392445 751823 SHILOH             9m
     81/ 2/14  ***m    3ha  BR2 S3
     DIST3  RAINpH: 4.3  1118mm
                                        0   2   6.1  5.87   69    51    87   43   357   445    5    64   228  0.0 111   321

2229 HASKELL MILLPOND     SALEM      NJ
     392926 752403 CANTON             2m
     81/ 2/14  2.3m   15ha  BR2 S5
     DIST4  RAINpH: 4.3  1118mm
                                        0   0   5.0  5.43   28    19    59   40    47   219    9    63    28  0.0 120   257
                                        2   3   4.9  5.96   19     5    31   44    91   433    9    60    59  0.0 112   395

2230 TUCKAHOE LAKE        CAPE MAY   NJ
     391630 744432 MARMORA            2m
     81/ 2/14  ***m    7ha  BR2 S5
     DIST3  RAINpH: 4.3  1118mm
                                        0   4   5.1  5.58   41    14    95   35   451   333   20    62   239  0.0 138   464

2231 RESERV ON OYSTER CR  OCEAN      NJ
     394733 741642 BROOKVILLE        14m
     81/ 2/13  ***m    9ha  BR2 S4
     DIST1  RAINpH: 4.3  1118mm
                                        0   3   4.6  4.57   -5   -20    19   41    55   153    4    58    34  0.0 118   106

2301 JONES MILL RUN       SOMERSET   PA
     400119 791554 SEVEN SPRINGS  676m
     80/ 7/21  ***m    3m   BR2 S2
     DIST2  RAINpH: 4.2  1118mm
                                        0  18   6.7  6.99  371   323    54   15   587  ****    3   152   133  0.0 313   112

2302 WEIKERT RUN          UNION      PA
     405022 771823 WEIKERT          268m
     80/ 7/17  ***m    5m   BR3 S5
     DIST3  RAINpH: 4.2  1041mm
                                        0  17   6.2  7.47  211   178    33   26   407  ****    6   133   162  0.0 186    61

2303 CLEAR SHADE CREEK    SOMERSET   PA
     400744 784448 OGLETOWN         691m
     80/ 7/21  ***m    6m   BR2 S3
     DIST2  RAINpH: 4.2  1168mm
                                        0  15   6.5  7.09  143   105    34   33   406  ****   **    74   199  0.0 147   198
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                                                 FLD  LAB   FEP    DEP
                                          D   T  pH   pH    ALK    ALK  COND  Al    Ca    Cl  CLR   K    Mg   Mn   Na    SO4
2305 LITTLE FISHING CREEK CENTRE      PA
     405322 773828 MINGOVILLE      402m
     81/ 3/31  ***m     4m   BR2 S5
     DIST2  RAINpH: 4.2  1016mm
                                          0   9  6.9  6.90  ***     88   37  160    51    20   9    82   113  0.0  66   258

2306 LITTLE SANDY CREEK   VENANGO     PA
     412258 795543 POLK            332m
     80/ 8/21  ***m     4m   BR2 S4
     DIST3  RAINpH: 4.1  1041mm
                                          0  18  7.4  7.91  741    713  108   37   650  ****   8    66   360 14.6 130   367

2307 LITTLE ALLEGHENY RES BLAIR       PA
     403110 782620 ALTOONA         397m
     81/ 6/30  ***m     4ha  BR3 S3
     DIST3  RAINpH: 4.2  1016mm
                                          0  24  7.6  8.04  429    411   88   15   205   176   3    26   138  0.0  25   169
                                          5  10  6.6  6.90  556    520  110    8   366   205   3    19   182 30.7  24   208

2308 FOWLER HOLLOW RUN    PERRY       PA
     401558 773515 BLAIN           290m
     80/ 8/26  ***m     3m   BR2 S5
     DIST1  RAINpH: 4.3  1067mm
                                          0  18  6.3  6.50   41    ***   37   29   169  ****  **    87    73  0.0 170   148

2309 N BR BOWMAN'S CREEK  LUZERNE     PA
     412123 761405 SWEET VALLEY    641m
     80/ 9/23  ***m     5m   BR2 S5
     DIST1  RAINpH: 4.3   965mm
                                          0  19  5.7  6.11   57     19   30   31   115  ****   3    81    53  0.0 157   208

2310 STRAIGHT RUN         TIOGA       PA
     414726 772417 ASAPH           384m
     80/ 7/24  ***m     3m   BR2 S5
     DIST2  RAINpH: 4.2   965mm
                                          0  22  7.2  8.04  513    475   71   31   519  ****   3    82   235 25.6 158   234

2311 UPPER THREE RUNS     CLEARFIELD PA
     411230 780745 DEVIL'S ELBOW   519m
     81/ 4/ 7  ***m     4m   BR2 S3
     DIST2  RAINpH: 4.2  1016mm
                                          0  **  ***  4.99   10    -29   41  133    34    19   1    75    67  2.9  36   249

2312 WYCKOFF RUN          CAMERON     PA
     411656 780800 DRIFTWOOD       323m
     81/ 7/16  ***m     9m   BR2 S3
     DIST2  RAINpH: 4.1  1016mm
                                          0  15  7.2  7.67  124     93   34   50    75    47   2    48    95  0.0  29   221

2313 RED RUN              ELK         PA
     411709 781439 DRIFTWOOD       370m
     81/ 8/17  ***m     8m   BR2 S3
     DIST2  RAINpH: 4.1  1016mm
                                          0  13  5.8  6.43   87     42   36   51    54    27   1    47    68  0.5  22   225
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                                             FLD  LAB   FEP    DEP
                                      D   T  pH   pH    ALK    ALK   COND  Al    Ca    Cl  CLR   K    Mg  Mn    Na   SO4
2314 GIPFORD RUN (LOWER)  CLEARFIELD PA
     411024 781430 DEVIL'S ELBOW  433m
     81/ 7/14  ***m    8m   BR2 S3
     DIST2  RAINpH: 4.1  1016mm
                                      0  24  6.0  7.57  167    130    34   85    44    28   5   61    71  0.7  29   370

2315 MOSQUITO CREEK       CLEARFIELD PA
     411254 781442 DEVIL'S ELBOW  464m
     81/ 7/14  ***m    9m   BR2 S3
     DIST2  RAINpH: 4.1  1016mm
                                      0  19  5.3  4.79   37    -56    33   62    41    16   5   53    55  3.0  20   269

2316 PEBBLE RUN           ELK        PA
     411535 781820 DENTS RUN      634m
     81/ 4/ 7  ***m    1m   BR2 S3
     DIST1  RAINpH: 4.1  1016mm
                                      0   9  4.8  4.54    0    -37    37  133    34    26   1   75    67  2.9  36   265

2317 DEER CREEK           CLEARFIELD PA
     411006 783053 THE KNOBS      580m
     81/ 4/ 7  ***m    2m   BR2 S3
     DIST1  RAINpH: 4.1  1016mm
                                      0   6  5.0  4.75   15    -15    39  141    30    34   2   77    62  2.0  34   249

2318 SIX MILE RUN         CENTRE     PA
     405510 780701 BLACK MOSHANNO 459m
     81/ 4/ 7  ***m    5m   BR2 S3
     DIST3  RAINpH: 4.2   965mm
                                      0   9  7.3  7.16  109     54    48   19    91    58   0   28    66  0.0  13   190

2319 GIPFORD RUN (UPPER)  CLEARFIELD PA
     411058 781723 THE KNOBS      537m
     81/ 4/ 7  ***m    3m   BR2 S3
     DIST2  RAINpH: 4.1  1016mm
                                      0   8  4.7  4.91   25    -10    28  395    29    18   0   57    41  1.2  16   241

2325 STONE VALLEY LAKE    HUNTINGTON PA
     403934 775500 PINE GROVE MIL 253m
     81/ 8/ 7  5.0m   27ha  BR4 S4
     DIST3  RAINpH: 4.2   965mm
                                      0  24  7.5  7.22  434    389    76    1   494    61   2   11   141  0.5  11    94
                                      8   9  6.9  6.91  800    751   115    0   720    97   4   10   192 43.9  13   111

2330 N FORK TANGASCOOTACK CLINTON    PA
     410945 773448 FARRANDSVILLE  204m
     81/ 7/29  ***m   10m   BR2 S2
     DIST2  RAINpH: 4.2   965mm
                                      0  14  6.2  6.87  120     69    34   17    97    23   3   28    70  0.7  13   161

2331 LITTLE BEAR CREEK    LYCOMING   PA
     412112 765331 HUNTERSVILLE   292m
     81/ 7/29  ***m    5m   BR2 S2
     DIST2  RAINpH: 4.2  1016mm
                                      0  15  6.3  6.65  102     41    22   18    67    50   3   27    48  0.5   9    57
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                                                 FLD  LAB   FEP   DEP
                                           D  T  pH   pH    ALK   ALK  COND  Al   Ca   Cl  CLR  K   Mg  Mn   Na  SO4
2332 TROUT RUN              LYCOMING   PA
     412342 770349 TROUT RUN       219m
     81/ 7/29  ***m     6m   BR3 S3
     DIST2  RAINpH: 4.2  1016mm
                                           0 16  6.7  6.75  238   195   44    6  166    1   3   16   71 0.5   8  195

2333 SLATE RUN              LYCOMING   PA
     413130 773151 LEE FIRE TOWER 308m
     81/ 7/29  ***m    10m   BR3 S3
     DIST2  RAINpH: 4.2   965mm
                                           0 16  6.9  8.43  333   259   54   13  201   34   2   24  123 0.6  21  143

2334 LEFT BR HYNER RUN    CLINTON    PA
     412430 773602 SLATE RUN       375m
     81/ 7/29  ***m     4m   BR3 S2
     DIST2  RAINpH: 4.2   965mm
                                           0 15  6.5  7.16  208   342   37   31   64   23   3   35   60 0.6  15   84

2335 COOK'S RUN             CLINTON    PA
     411819 775557 KEATING         345m
     81/ 7/29  ***m     6m   BR2 S2
     DIST2  RAINpH: 4.2   965mm
                                           0 17  7.0  7.12  193   162   53   23  117    7   8   32   99 0.5  22  145

2336 LONG PINE RUN RESER  ADAMS       PA
     395618 772615 CALEDONIA PARK 415m
     81/ 7/31  6.0m    55ha  BR3 S2
     DIST2  RAINpH: 4.3  1016mm
                                           0 25  5.9  7.21   63    40   23   56   37   34   3   49   47 1.9  16   94
                                          16 23  5.3  5.83   18    -9   41   65   37   35   3   53   51 2.2  19   96

2337 RED LION RESERVOIR   YORK        PA
     395633 763455 RED LION        183m
     81/ 7/31  3.5m     4ha  BR3 S2
     DIST2  RAINpH: 4.3  1016mm
                                           0 26  7.3  7.25  532   461  107   13  340  165   3   32  286 1.0  66  661
                                           7 15  6.8  6.89 1837  1805  191   15  745  205   5   26  482 ***  88    5

2338 OPOSSUM LAKE           CUMBERLAND PA
     401432 771637 PLAINFIELD      137m
     81/ 7/31  4.0m    24ha  BR2 S2
     DIST3  RAINpH: 4.2  1016mm
                                           0 28  8.2  8.58  610   569  101   45  257  114   3   45  299 2.9  94  733
                                           7 16  6.3  6.69  726   647  120   33  323  114   5   37  326 ***  85  890

2339 LETTERKENNY RESERVOI FRANKLIN    PA
     400651 774126 ROXBURY         267m
     81/ 7/31  4.0m    27ha  BR2 S3
     DIST2  RAINpH: 4.3  1016mm
                                           0 24  6.9  7.53  545   534   67    3  489    4   5   12  159 0.6  13   96
                                           4 14  6.9  7.29  609   572   70    3  499   33   6   12  157 3.0  13  143
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                                               FLD  LAB   FEP   DEP
                                         D  T  pH   pH    ALK   ALK  COND  Al    Ca    Cl CLR    K    Mg  Mn   Na   SO4
2340 HILL'S CREEK LAKE    TIOGA       PA
     414815 771142 CROOKED CREEK  453m
     81/ 8/ 3  1.5m    51ha  BR2 S2
     DIST4  RAINpH: 4.2   914mm
                                         0  24  7.7  8.34  681   643  103    0   704   105   7     8   168  2.3  10   249
                                         5  20  6.5  7.39  744   694  106    0   667    80   7     9   167 14.2  11   245

2341 FOURMILE RUN         TIOGA       PA
     414134 772932 TIADAGHTON     494m
     81/ 8/ 3  ***m     1m   BR3 S3
     DIST2  RAINpH: 4.2   965mm
                                         0  14  6.9  8.46  527   476   80    0   432    61   2    10   114  0.7   8   256

2342 LYMAN RUN RESERVOIR  POTTER      PA
     414324 774544 CHERRY SPRINGS 494m
     81/ 8/ 3  3.0m    18ha  BR2 S2
     DIST3  RAINpH: 4.1   965mm
                                         0  22  6.3  7.91  402   361   67    9   239    43   2    20    12  0.8  17   137
                                         6  14  6.2  7.26  282   245   55   10   211    35   2    21   115  4.7  16   158

2343 W BR DINGMAN'S RUN   POTTER      PA
     414641 780308 COUDERSPORT    525m
     81/ 8/ 3  ***m     2m   BR2 S2
     DIST2  RAINpH: 4.1  1016mm
                                         0  16  6.4  6.91  176   136   58   29   109   540   3    36   102  0.0  25   343

2344 TROUT BROOK          POTTER      PA
     414702 780649 COUDERSPORT    506m
     81/ 8/ 3  ***m     3m   BR2 S2
     DIST2  RAINpH: 4.1  1016mm
                                         0  17  6.8  6.95  192   150   70   15   211   232   2    26   143  0.7  27   253

2345 SKINNER CREEK        McKEAN      PA
     414748 782053 PORT ALLEGANY  549m
     81/ 8/ 3  ***m     4m   BR2 S2
     DIST2  RAINpH: 4.1  1016mm
                                         0  18  7.0  7.65  493   458   79    4   341    97   5    14   123  1.0  12   201

2346 SALT RUN             CAMERON     PA
     413130 781238 EMPORIUM       345m
     81/ 8/ 3  ***m     8m   BR3 S2
     DIST3  RAINpH: 4.1  1016mm
                                         0  20  6.8  8.14  365   328   73   11   257    42   4    22   151  0.9  23   236

2347 BELMOUTH RUN         ELK         PA
     412102 784622 CARMAN         547m
     81/ 8/ 4  ***m     2m   BR3 S2
     DIST2  RAINpH: 4.1  1067mm
                                         0  14  5.7  6.71   83    51   34   48    63    15   2    47    75  1.3  23   153

2348 ROCK RUN             FOREST      PA
     413530 790345 LYNCH          476m
     81/ 8/ 4  ***m     2m   BR3 S2
     DIST2  RAINpH: 4.1  1067mm
                                         0  15  5.1  5.39   65    37   40   30    65    13   2    36    61  2.8  15   387
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                                               FLD  LAB   FEP   DEP
                                          D  T  pH   pH    ALK   ALK  COND  Al    Ca    Cl CLR   K    Mg   Mn  Na   SO4
2349 McLAUGHLIN CREEK     CRAWFORD   PA
     414018 794233 TITUSVILLE NOR 406m
     81/ 8/ 4  ***m    6m  BR4 S2
     DIST3  RAINpH: 4.1  1392mm
                                          0 18 6.8 8.56 1313   918  225    4   928   126  9   13   343  0.5 32   215

2350 WOODCOCK CREEK       CRAWFORD   PA
     413953 795754 TOWNVILLE      403m
     81/ 8/ 4  ***m    4m  BR2 S2
     DIST3  RAINpH: 4.1  1367mm
                                          0 22 6.5 7.39 1165  1119  155    3  1075   102  9   11   330 22.1 27   288

2351 TAMARACK LAKE        CRAWFORD   PA
     413450 803442 COCHRANTON     371m
     81/ 8/ 4  1.0m  231ha  BR2 S2
     DIST3  RAINpH: 4.1  1341mm
                                          0 26 7.6 8.93  425   369   97    4   482   163 11   14   177  1.7 17   174
                                          4 24 6.3 7.31  503   448   89    4   464   784  7   14   182  8.8 17   148

2352 FRENCH CREEK         CRAWFORD   PA
     414250 800833 MEADVILLE      334m
     81/ 8/ 4  ***m   20m  BR2 S2
     DIST4  RAINpH: 4.1  1041mm
                                          0 25 7.6 8.02 1429  1369  232    3  1696   314 10   11   520  3.9 42   484

2353 PINE RUN             MERCER     PA
     411125 801155 MERCER         361m
     81/ 8/ 4  ***m    3m  BR4 S2
     DIST3  RAINpH: 4.2  1316mm
                                          0 20 7.5 8.31 2642  2577   77    8  3879   632  5   18  1792  1.8 235 2953

2354 GLADE RUN RESERVOIR  BUTLER     PA
     404257 795412 VALENCIA       336m
     81/ 8/ 9  0.5m   19ha  BR3 S4
     DIST2  RAINpH: 4.1   965mm
                                          0 26 8.5 8.73  929   865  173    5  1203   189  7   14   452  2.8 48   547
                                          4 20 6.8 7.19 1606  1533  211    5  1201   191  9   15   483  *** 50   281

2355 PENN ROOSEVELT LAKE  CENTRE     PA
     404337 774205 BARRVILLE      496m
     81/ 8/ 5  ***m    2m  BR2 S2
     DIST1  RAINpH: 4.2  1316mm
                                          0 17 5.7 6.23   54    18   15  103    25     5  3   68    44  0.5 21    50
                                          2 13 5.9 6.16   59    13   23  101    28    52  4   66    48  0.6 22    41

2357 E BR STANDING STONE  HUNTINGDON PA
     403855 774535 McALEVY'S FORT 256m
     81/ 7/ 8  ***m    6m  BR3 S2
     DIST3  RAINpH: 4.2   965mm
                                          0 14 6.3 7.18   95    63   35   54    61    34  3   47    78  0.5 26   153

2358 GLOBE RUN            HUNTINGDON PA
     403853 775953 PINE GROVE MIL 278m
     81/ 7/ 8  ***m    6m  BR4 S3
     DIST1  RAINpH: 4.2   965mm
                                          0 16 6.3 6.95   86    58   34   66    70    21  5   54    98  3.9 37   127
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                                                     FLD  LAB    FEP    DEP
                                              D   T   pH   pH    ALK    ALK  COND   Al     Ca     Cl CLR    K    Mg  Mn   Na    SO4
2359 HIGH POINT LAKE        SOMERSET   PA
     394656 791356 MARKLETON         756m
     81/ 7/15  1.3m  111ha  BR2 S2
     DIST3  RAINpH: 4.3  1168mm
                                              0  25  6.9 7.79  749    707    86    0    559     57   5    7   102 1.8    5   778
                                              5  24  7.0 7.60  564    513    71    0    558     33   5    7   102 3.5    5   473

2360 JORDON CREEK           LEHIGH     PA
     403717 753314 ALLENTOWN WEST  98m
     81/ 7/28  ***m   20m   BR4 S4
     DIST4  RAINpH: 4.3  1118mm
                                              0  23  8.1 8.36  846    804   188    5   1279    332   7   15   492 0.8   51   494

2361 ANTIETAM RESERVOIR     BERKS      PA
     402124 755217 BIRDSBORO         159m
     81/ 7/28  1.0m    7ha  BR4 S4
     DIST3  RAINpH: 7.2  1392mm
                                              0  24  9.0 7.59  966    925   145   31    411    204  10   36   389 0.0   99  1080
                                             10  19  6.4 7.64  962    920   156   38    344    207  14   42   381 7.3  135   292

2362 CRABBY CREEK           CHESTER    PA
     400259 752803 VALLEY FORGE    98m
     81/ 7/29  ***m    3m   BR4 S2
     DIST3  RAINpH: 4.3  1118mm
                                              0  18  7.3 8.27 1467   1404   368   30   1405    866   5   36  1265 0.0  324   610

2363 VALLEY CREEK           CHESTER    PA
     400301 753330 MALVERN            87m
     81/ 7/29  ***m    3m   BR4 S4
     DIST4  RAINpH: 7.3  1118mm
                                              0  17  7.5 7.15 1802   1748    49   23   2357   1329   2   31  2011 0.0  422   741

2364 PICKERING CREEK        CHESTER    PA
     400605 753213 MALVERN            49m
     81/ 7/29  ***m   35m   BR2 S5
     DIST3  RAINpH: 4.3  1118mm
                                              0  22  7.5 8.43  879    842   180   18    702    423   7   28   502 0.5  100   351

2365 MARSH CREEK LAKE       CHESTER    PA
     400343 754313 DOWNINGTOWN       110m
     81/ 7/29  3.3m  217ha  BR3 S3
     DIST3  RAINpH: 4.3  1392mm
                                              0  26  8.9 8.72  610    569   160   12    552    680   5   23   333 0.6   53   249
                                              9  20  6.7 7.37  574    518    94   13    574    442   5   24   345 11.1  58   796

2366 YMCA CAMP POND         LEBANON    PA
     401443 762337 MANHEIM           226m
     81/ 7/29  1.5m    1ha  BR3 S2
     DIST3  RAINpH: 4.2  1067mm
                                              0  24  7.3 8.04  582    545    86   92    125    109  11   65   211 0.8   56   111
                                              2  22  6.9 8.03  685    634    97   98    192    115  13   67   176 1.4   83   101
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                                               FLD  LAB   FEP   DEP
                                     D    T    pH   pH    ALK   ALK  COND  Al    Ca    Cl  CLR   K     Mg   Mn   Na   SO4
2367 HOWE RUN              PERRY     PA
     403020 773522 REWARD         192m
     81/ 7/29  ***m    4m   BR2 S2
     DIST4  RAINpH: 4.2  1067mm
                                     0   17   6.0  7.66   613   583   47  179    44    88   2    90    98  0.7  62   327

2368 BELL HOLLOW RUN       CENTRE    PA
     404812 780839 SANDY RIDGE    461m
     81/ 7/31  ***m    3m   BR2 S2
     DIST3  RAINpH: 4.2   965mm
                                     0   14   6.9  7.25   109    72   34   40    73     5   2    42    77  0.0  22   160

2369 LAUREL RUN            CLEARFIELD PA
     405346 784333 MAHAFFEY       387m
     81/ 7/31  ***m    6m   BR3 S4
     DIST2  RAINpH: 4.2  1118mm
                                     0   14   6.8  6.77   136    90   94   55   207    63   3    49   271  0.0  90   507

2370 MUDLICK RUN           INDIANA   PA
     405208 790249 MARION CENTER  397m
     81/ 7/31  ***m    5m   BR3 S4
     DIST4  RAINpH: 4.2  1067mm
                                     9   15   7.1  8.53   317   271  118   21   332   166   2    30   259  1.2  54   296

2371 BRUSH CREEK           INDIANA   PA
     403135 790152 BRUSH VALLEY   436m
     81/ 7/31  ***m    6m   BR2 S4
     DIST3  RAINpH: 4.3  1118mm
                                     0   16   6.9  7.80   194   125   73   36   180   245   2    38   183  1.1  50   303

2372 LITTLE SALTLICK RUN  CAMBRIA    PA
     402412 784843 NANTY GLO      543m
     81/ 7/31  ***m    3m   BR3 S4
     DIST2  RAINpH: 4.2  1168mm
                                     0   14   4.4  4.55    13   -79   63   86    70    63   7    63   110  7.8   3   383

2373 STEWART RUN           CAMBRIA   PA
     402616 784751 NANTY GLO      601m
     81/ 7/31  ***m    3m   BR4 S4
     DIST2  RAINpH: 4.2  1143mm
                                     0   16   6.8  6.63   133    58   84   30   154   192   3    36   150  1.4  37   288

2374 ARCH SPRING           BLAIR     PA
     403620 781214 SPRUCE CREEK   273m
     81/ 7/31  ***m    2m   BR4 S2
     DIST2  RAINpH: 4.2  1016mm
                                     0   16   7.1  7.62  1181  1120  164    5  1083    97   3    14   407  0.0  42   298

2375 BLUE HOLE CREEK       SOMERSET  PA
     395807 791731 KINGWOOD       591m
     81/ 7/15  ***m    5m   BR2 S4
     DIST2  RAINpH: 4.1  1118mm
                                     0   13   6.5  6.15   204   157   37   39    38    21   5    42    95  0.0  20   413
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	D	T	FLD pH	LAB pH	FEP ALK	DEP ALK	COND	Al	Ca	Cl	CLR	K	Mg	Mn	Na	SO_4
2376 SAW CREEK PIKE PA 410758 750138 TWELVEMILE PON 308m 81/ 6/25 ***m 5m BR3 S2 DIST2 RAINpH: 4.3 1168mm																
	0	22	6.2	6.03	113	91	26	5	113	63	100	15	45	0.0	4	67
2377 LITTLE BUSH KILL PIKE PA 411023 750037 TWELVEMILE PON 345m 81/ 6/25 ***m 7m BR2 S2 DIST3 RAINpH: 4.3 1143mm																
	0	24	6.6	6.42	49	40	27	22	98	39	60	32	79	7.1	16	94
2378 BRODHEAD CREEK MONROE PA 410058 751155 E STROUDSBURG 133m 81/ 6/25 ***m 6m BR3 S3 DIST4 RAINpH: 4.3 1219mm																
	0	19	6.6	7.40	208	185	53	20	139	155	4	29	111	0.5	22	122
2379 UNITY RESERVOIR WESTMORELA PA 401650 793000 LATROBE 387m 81/ 7/15 3.0m 19ha BR4 S4 DIST4 RAINpH: 4.3 1016mm																
	0	25	6.9	8.24	462	411	126	9	551	154	5	21	299	0.0	41	900
	14	11	6.6	7.08	462	407	131	8	588	145	3	20	299	15.6	41	965
2380 REDSTONE CREEK FAYETTE PA 395035 794222 BROWNFIELD 436m 81/ 7/15 ***m 2m BR3 S2 DIST1 RAINpH: 4.3 1092mm																
	0	16	6.6	6.71	227	166	58	29	143	42	3	34	130	0.4	32	169
2381 DEER VALLEY LAKE SOMERSET PA 394745 791135 MARKLETON 809m 81/ 7/15 3.5m 45ha BR2 S2 DIST3 RAINpH: 4.3 1143mm																
	0	25	6.4	6.82	106	51	43	3	188	75	3	13	62	2.6	5	175
	5	23	6.3	6.91	139	78	42	3	197	50	4	12	60	2.4	5	163
2382 NORTH FORK RESERVOIR SOMERSET PA 401608 790023 RACHELWOOD 466m 81/ 7/15 4.0m 39ha BR2 S4 DIST2 RAINpH: 4.2 1143mm																
	0	25	7.5	8.00	524	483	74	21	170	****	5	30	138	0.4	28	292
	5	16	6.4	6.78	164	125	63	28	149	57	5	35	135	0.9	33	314
2383 COWAN'S GAP LAKE FULTON PA 400005 775530 BURNT CABINS 371m 81/ 7/11 2.8m 20ha BR3 S2 DIST3 RAINpH: 4.3 965mm																
	0	27	6.2	5.77	100	67	33	42	71	58	5	44	80	1.6	24	96
	4	17	6.0	6.26	100	67	34	45	67	58	8	44	79	6.4	25	96
2384 BEAVERDALE RESERVOIR CAMBRIA PA 401620 784101 BEAVERDALE 728m 81/ 7/ 8 1.5m 20ha BR5 S2 DIST1 RAINpH: 4.2 1118mm																
	0	22	5.7	6.33	31	4	27	29	54	21	3	35	51	2.4	12	57
	8	15	5.5	6.45	45	13	27	32	56	23	3	37	53	2.5	14	46

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                                           FLD  LAB   FEP   DEP
                                     D   T  pH   pH    ALK   ALK  COND  Al    Ca    Cl  CLR   K    Mg  Mn   Na    SO4

2385 SPORTSMAN'S LAKE     BEDFORD    PA
     395754 782957 CLEARVILLE     437m
     81/ 7/ 8  2.5m    6ha  BR4 S4
     DIST4  RAINpH: 4.3   965mm
                                     0  27  6.9  7.59  154   122   49   33   156    39   3   37   154  0.0  42   163
                                     6  16  6.9  7.98  268   226   70   27   187    65   3   35   172  3.2  43   304

2386 LAUREL RUN           HUNTINGDON PA
     402015 780608 CASSVILLE      424m
     81/ 7/ 8  ***m    3m   BR2 S2
     DIST2  RAINpH: 4.2  1016mm
                                     0  14  5.6  6.42   53     6   34  266    27    33   2  106    78  0.5  61   184

2387 SUNFISH POND         BRADFORD   PA
     413840 764148 LEROY          632m
     81/ 7/ 7  2.0m   19ha  BR2 S2
     DIST2  RAINpH: 4.2   914mm
                                     0  25  7.4  6.16   40     9   25    4   118    35   3   14    46  2.3   4    84
                                     3  23  7.4  5.95   43    22   24    4   126    31   3   13    44  2.5   4    78

2388 OLYMPIC LAKE         SUSQUEHANN PA
     415559 765818 FRIENDSVILLE   503m
     81/ 7/ 7  2.5m   19ha  BR3 S3
     DIST3  RAINpH: 4.2   914mm
                                     0  25  7.1  7.41  172   145   39    9   142    42   4   21    76  4.7  10   101
                                     5  22  7.2  6.93  149   113   36   11   166    35   5   21    93  1.7  14   101

2389 TUSCARORA LAKE       SUSQUEHANN PA
     414420 760520 AUBURN CENTER  354m
     81/ 7/ 7  0.5m   25ha  BR3 S3
     DIST2  RAINpH: 4.2   914mm
                                     0  25 10.3  9.33  299   262   55   11   120    63  17   22    71  1.8  11    94
                                     5  13  6.5  6.36  502   471   70    9   296    44   8   20   153 16.0  22    35

2390 LAKE JEAN            LUZERNE    PA
     412009 761800 REDROCK        678m
     81/ 7/ 7  3.0m  100ha  BR2 S2
     DIST3  RAINpH: 4.2  1016mm
                                     0  22  5.5  6.21   27     0   10    0    61    29   3    8    13  1.8   0    89
                                     4  23  5.5  6.66   31     2   29    0   145    52   3    5    19  2.3   0   122

2391 SILVER LAKE          PIKE       PA
     411520 745845 EDGEMERE       399m
     81/ 6/25  5.5m   57ha  BR4 S2
     DIST3  RAINpH: 4.3  1118mm
                                     0  23  6.1  6.42   40    13   26    8   111    26   4   19    55  1.0   7   111
                                    15  23  6.4  6.57   45    18   26    9   105    19   3   20    54  1.0   8   101

2392 DEEP LAKE            MONROE     PA
     410310 752350 POCONO PINES   557m
     81/ 6/25  3.5m    4ha  BR5 S2
     DIST1  RAINpH: 4.3  1341mm
                                     0  22  5.2  4.85   22     0   23    6    64    34   1   16    28  3.9   3    76
                                     7  21  5.2  4.36   19     0   23    6    61    34   3   17    27  3.9   3    62
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                                                     FLD   LAB    FEP     DEP
                                              D   T  pH    pH     ALK     ALK   COND   Al     Ca    Cl   CLR    K     Mg   Mn    Na    SO4
2393 SHADIGEE CREEK          WAYNE       PA
     415353 752748 STARRUCCA         409m
     81/ 6/22  ***m    10m    BR3 S2
     DIST4  RAINpH: 4.2  1067mm
                                              0  20  7.8  7.75   434     398    84     0    445   182   10      8    95  1.3    5     89
2394 LONG POND               WAYNE       PA
     414000 752037 ALDENVILLE        414m
     81/ 6/22  3.5m    33ha   BR2 S2
     DIST4  RAINpH: 4.3  1118mm
                                              0  24  7.9  7.44   199     172    49     0    274    52   10      9    64  0.9    4    132
                                              0  24  7.9  6.98   294     267    60     0    121    79   10      7    24  5.8    1    101
2395 W BR DYBERRY CREEK    WAYNE         PA
     413937 751725 ALDENVILLE        317m
     81/ 6/22  ***m    10m    BR2 S2
     DIST2  RAINpH: 4.3  1118mm
                                              0  21  7.9  8.56   489     453    80     0    360   134   10      8    77  0.7    4    117
2396 DYBERRY CREEK           WAYNE       PA
     413543 751632 HONESDALE         296m
     81/ 6/22  ***m    15m    BR2 S2
     DIST4  RAINpH: 4.3  1118mm
                                              0  21  7.9  7.93   443     411    81     0    492   121   10      8    99  1.1    5    137
2397 LACKAWAXEN RIVER        WAYNE       PA
     413435 751615 HONESDALE         316m
     81/ 6/22  ***m    25m    BR2 S2
     DIST4  RAINpH: 4.3  1118mm
                                              0  23  7.8  8.82   348     312    77     0    397   142    9      9    98  2.6    6    153
2398 LAKE LACAWAC            WAYNE       PA
     412236 751731 HAWLEY            439m
     81/ 6/22  3.5m    21ha   BR2 S2
     DIST1  RAINpH: 4.3  1169mm
                                              0  24  6.0  6.04    95      77    35     2    168    34   10     11    49  1.6    3    106
                                             11  12  5.8  5.95   100      67    35     0    179    29   10      9    44  4.5    2     84
2399 WALLENPAUPACK CREEK  PIKE           PA
     411355 751855 NEWFOUNDLAND      393m
     81/ 6/22  ***m    15m    BR2 S2
     DIST4  RAINpH: 4.3  1169mm
                                              0  19  7.6  7.99   285     249    67     0    280   134    5     10    79  0.5    6    101
2401 CUBBAGE POND            SUSSEX      DE
     385156 752339 ELLENDALE           4m
     80/11/ 7  1.5m    11ha   BR3 S4
     DIST3  RAINpH: 4.5  1118mm
                                              0  11  6.5  6.62   337     309    93    26    230   271   13     94    86  0.8  188     57
                                              2  10  6.2  7.05   342     314    95    33    240   254   18     58   115  0.8  150     52
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                                                  FLD  LAB   FEP   DEP
                                        D   T   pH   pH    ALK   ALK  COND  Al    Ca    Cl  CLR    K    Mg  Mn    Na    SO4
2402 SILVER LAKE 2         NEW CASTLE DE
     393726 754332 SAINT GEORGES   15m
     80/11/ 4  0.5m   18ha  BR2 S4
     DIST3  RAINpH: 4.3  1118mm
                                        0  13  7.0  7.07  432   394  102   68   285   340   5    42   285  5.2  73   309
                                        3  14  7.0  6.34  408   380  128   76   302   337  12    33   338  5.1  64   314

2403 LUMS POND             NEW CASTLE DE
     393345 754357 SAINT GEORGES   13m
     80/11/ 4  0.6m   77ha  BR2 S4
     DIST3  RAINpH: 4.3  1118mm
                                        0  10  6.0  7.26  480   442  130   41   632   385   2    62   389  1.7 117   452
                                        1  11  6.2  7.47  480   447  128   35   651   343   3    80   345  1.2 141   432

2404 SMALLCROSS LAKE       NEWCASTLE  DE
     393054 754026 MIDDLETOWN      12m
     80/11/ 4  0.5m   19ha  BR2 S3
     DIST4  RAINpH: 4.3  1118mm
                                        0  10  7.0  7.19  722   637  176   55   839   343   8    42   661  4.3  90   361
                                        3  10  6.6  7.00  632   579  195   61  1073   353   5    39   973  3.4  82   364

2405 MORRIS MILLPOND       SUSSEX     DE
     383844 751854 HARBESON         7m
     80/11/ 7  0.9m   18ha  BR3 S3
     DIST3  RAINpH: 4.5  1118mm
                                        0   9  6.0  6.59  332   308   91   45   121   311   2    58    78  2.6 109   182
                                        1   9  6.2  6.78  361   328   89   41   165   306  25    62   101  2.6 120   140

2406 SILVER LAKE 1         NEW CASTLE DE
     392616 754222 MIDDLETOWN      12m
     80/11/ 4  0.5m   11ha  BR2 S3
     DIST3  RAINpH: 4.4  1118mm
                                        0  10  6.7  7.23  608   579  211   49   585   538   6    45   424 10.3  99   614
                                        3  10  6.5  7.08  618   566  211   53   593   551   4    49   468 12.1  93   611

2407 HAVEN LAKE            KENT       DE
     385446 752703 MILFORD          4m
     80/11/ 6  0.9m   33ha  BR3 S4
     DIST4  RAINpH: 4.5  1118mm
                                        0  11  6.3  6.97  366   337   99   36   407   306  20    68   215  3.4 136   202
                                        2  12  6.7  6.91  328   295  102   54   349   311  20    41   275  3.4  92   216

2408 TRAP POND             SUSSEX     DE
     383126 752823 TRAP POND      100m
     80/11/ 6  1.1m   43ha  BR3 S3
     DIST3  RAINpH: 4.5  1118mm
                                        0  10  6.4  6.83  190   162   57   45    34   193  14    50    23  1.7 109   119
                                        1  10  6.2  6.62  190   157   57   41    73   213  10    54    45  1.7 117   145

2409 LAKE COMO             KENT       DE
     391730 753613 SMYRNA           6m
     80/11/ 5  0.3m   17ha  BR3 S4
     DIST4  RAINpH: 4.4  1118mm
                                        0   9  5.9  6.51  318   285  140   97   353   335   8    29   506 10.4  51   439
                                        2  10  6.4  6.96  342   309  134   88   369   343   1    27   488 11.0  55   473
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	D	T	FLD pH	LAB pH	FEP ALK	DEP ALK	COND	Al	Ca	Cl	CLR	K	Mg	Mn	Na	SO_4
2410 GARRISONS LAKE KENT DE 391523 753522 DOVER 3m 80/11/ 5 0.5m 35ha BR3 S4 DIST4 RAINpH: 4.4 1118mm																
	0	9	7.0	7.19	731	660	174	90	587	377	13	30	793	6.1	54	450
	1	9	7.2	7.19	674	641	167	71	586	417	18	43	601	6.8	69	458
2411 MASSEY'S MILLPOND KENT DE 391421 753732 DOVER 5m 80/11/ 5 0.5m 15ha BR3 S4 DIST4 RAINpH: 4.4 1118mm																
	0	10	7.0	7.17	750	718	224	56	666	443	10	40	540	5.1	86	523
	1	10	7.0	7.11	741	703	211	58	773	427	6	42	671	6.0	64	523
2412 CHIPMAN POND SUSSEX DE 383345 753220 LAUREL 6m 80/11/ 6 1.1m 13ha BR3 S3 DIST3 RAINpH: 4.5 1118mm																
	0	10	6.4	6.95	280	252	94	31	418	274	15	74	190	0.8	158	202
	1	11	6.7	7.10	285	257	96	29	382	277	18	98	163	1.7	168	223
2413 FLEETWOOD POND SUSSEX DE 383838 753032 SEAFORD EAST 9m 80/11/ 6 ***m 12m BR3 S3 DIST3 RAINpH: 4.5 1118mm																
	0	10	6.1	6.33	276	248	81	32	115	213	5	87	55	1.7	148	93
2414 MUD MILLPOND KENT DE 390413 754456 MARYDEL 11m 80/11/ 5 ***m 5m BR3 S5 DIST3 RAINpH: 4.5 1118mm																
	0	12	6.8	6.38	314	295	124	49	312	340	3	48	225	1.7	172	411
2415 WYOMING LAKE KENT DE 390740 753320 DOVER 9m 80/11/ 5 0.5m 21ha BR3 S4 DIST4 RAINpH: 4.4 1118mm																
	0	10	6.9	6.45	379	347	141	42	314	361	10	62	193	2.6	118	315
	1	10	7.2	6.94	370	342	152	42	399	377	15	54	250	3.4	115	348
2416 VOSHELL MILLPOND KENT DE 390535 753148 WYOMING 6m 80/11/ 5 0.5m 15ha BR3 S4 DIST3 RAINpH: 4.4 1118mm																
	0	11	6.9	6.50	338	314	135	44	402	427	9	50	257	4.2	112	434
	2	10	7.2	6.55	323	290	169	49	360	448	9	58	259	4.3	100	416
2417 ANDREWS LAKE KENT DE 390130 753032 WYOMING 3m 80/11/ 6 0.6m 7ha BR3 S4 DIST4 RAINpH: 4.4 1118mm																
	0	9	6.1	6.47	276	257	143	41	246	366	10	53	149	6.0	117	369
	1	9	6.1	6.77	237	235	131	44	280	395	14	52	185	6.0	110	369

BEST COPY AVAILABLE

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                                                  FLD  LAB    FEP    DEP
                                            D   T   pH   pR     ALK    ALK   COND   Al    Ca    Cl   CLR    K    Mg  Mn    Na    SO4
2418 MARSHY HOPE CREEK     KENT        DE
     385050 754025 HICKMAN           12m
     80/11/ 6  ***m    7m   BR3 S4
     DIST3  RAINpH: 4.5  1118mm
                                            0   8  6.4  6.82   261    228    88    49   365   279    3    56   266  5.2   99   346

2419 KILLENS POND          KENT        DE
     385753 753154 HARRINGTON         5m
     80/11/ 6  0.5m   33ha  BR3 S4
     DIST3  RAINpH: 4.4  1118mm
                                            0   9  6.5  6.80   285    257   153    45   479   372   25    55   324  5.2  107   593
                                            2   9  6.6  6.50   291    266   150    42   492   377   22    62   310  4.3  113   586

2420 COLLINS POND          SUSSEX      DE
     384236 753123 SEAFORD EAST       9m
     80/11/ 6  0.9m   38ha  BR3 S4
     DIST3  RAINpH: 4.5  1118mm
                                            0  10  5.9  6.42   181    147    51    44    77   168    8    55    50  1.7  110   140
                                            2   9  6.0  6.48   193    162    54    50   113   145    8    44    82  1.7   99   166

2421 HEARNS POND           SUSSEX      DE
     384041 753544 SEAFORD EAST       8m
     80/11/ 6  0.8m   23ha  BR3 S4
     DIST4  RAINpH: 4.5  1118mm
                                            0  10  6.3  5.66   373    338   114    35   307   308    8    68   206  2.6  126   299
                                            1  10  6.2  6.71   366    324   111    39   369   298    8    81   157  3.4  139   333

2502 BLAIR VALLEY LAKE     WASHINGTON MD
     394156 775635 CLEAR SPRING     210m
     81/ 2/17  1.5m   11ha  BR2 S5
     DIST3  RAINpH: 4.3   965mm
                                            0   0  6.7  7.53   444    407    89    34   557    63   21    67   283  0.0  144   390
                                            8   4  6.9  7.19   707    680   136    37   779    50    5    76   420  0.0  131   432

2503 ROCKY GAP RUN         ALLEGANY    MD
     394257 783816 EVITTS CREEK     357m
     80/12/27  ***m    2m   BR4 S3
     DIST2  RAINpH: 4.3   914mm
                                            0   0  6.7  6.61  1369   1406   183    34   184   147    3    74    94  0.0  141   385

2504 PINEY CREEK           GARRETT     MD
     394218 790035 AVILTON          711m
     80/12/27  ***m    4m   BR3 S4
     DIST2  RAINpH: 4.3  1168mm
                                            0   1  6.2  5.83   185    148   107    55   437   427    4    44   350  1.7   89   281

2505 CRABTREE CREEK        GARRETT     MD
     393916 790920 BITTINGER        860m
     80/12/27  ***m    5m   BR2 S2
     DIST2  RAINpH: 4.3  1219mm
                                            0   1  6.1  6.17   435    388   124    47   618   184    5    61   429  0.0  135   377
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                                                  FLD  LAB   FEP    DEP
                                         D    T   pH   pH    ALK    ALK  COND  Al    Ca    Cl  CLR    K    Mg  Mn   Na    SO4
2506 LAKE HABEEB            ALLEGANY   MD
     394205 783912 EVITTS CREEK    356m
     81/ 2/17  1.5m    79ha  BR4 S4
     DIST2  RAINpH: 4.3   914mm
                                         0    0  7.3  8.13   615    578   88   46   825    35    3   49   552 1.7 106   339
                                        15    1  7.2  8.32   553    518   95   30   633    38    8   92   283 0.0 162   343

2507 FROSTBURG RESERVOIR  GARRETT      MD
     394240 790026 AVILTON         717m
     81/ 2/17  2.0m    12ha  BR3 S3
     DIST2  RAINpH: 4.3  1168mm
                                         0    0  6.3  6.86   124     62   69   34   184   219    4   74    94 0.0 141   278
                                         5    2  6.3  6.35   146    128  458   55   437  ****    5   44   350 1.7  89   351

2508 GRAVELLY RUN           GARRETT    MD
     393214 792042 McHENRY         753m
     80/12/27  ***m      2m   BR2 S3
     DIST3  RAINpH: 4.3  1270mm
                                         0    0  6.1  6.83   106     93   40   27   139    35    0   92    55 0.0 180   208

2509 GUNPOWDER FALLS        BALTIMORE  MD
     394126 764650 LINESBORO       183m
     80/12/29  ***m     10m   BR2 S5
     DIST2  RAINpH: 4.3  1118mm
                                         0    0  6.8  6.92   527    481  104   37   598   139    3   70   336 0.0 130   105

2510 MERRYMAN BRANCH        BALTIMORE  MD
     392738 763521 TOWNSON          91m
     80/12/29  ***m      2m   BR4 S5
     DIST3  RAINpH: 4.3  1168mm
                                         0    1  6.9  7.13   795    777  182   31   954   768    3   90   449 0.0 156   230

2511 CHIMNEY BRANCH         BALTIMORE  MD
     392426 765133 REISTERSTOWN     91m
     80/12/29  ***m      2m   BR2 S5
     DIST4  RAINpH: 4.3  1118mm
                                         0    1  7.5  7.59  2812   2760  238   20   121    35    3  127    37 0.0 239   216

2512 NORTH FORK CREEK       FREDERICK  MD
     392746 771121 LIBERTYTOWN     131m
     80/12/29  ***m      4m   BR2 S4
     DIST4  RAINpH: 4.3  1067mm
                                         0    1  7.0  7.24   421    384   46   36   487   232    0   71   262 0.0 136    93

2513 OWENS CREEK            FREDERICK  MD
     393506 772008 WOODSBORO        88m
     80/12/29  ***m      5m   BR3 S4
     DIST4  RAINpH: 4.3  1041mm
                                         0    0  7.4  7.38  1341   1244  207   30   995   345    3   93   443 0.0 160   513

2514 HUNTING CREEK          FREDERICK  MD
     393752 772718 BLUE RIDGE SUM 283m
     80/12/29  ***m      3m   BR2 S4
     DIST2  RAINpH: 4.3  1316mm
                                         0    3  7.0  7.11   541    454  104   39   459   216    3   57   257 0.0 128   218
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115.

	D	T	FLD pH	LAB pH	FEP ALK	DEP ALK	COND	Al	Ca	Cl	CLR	K	Mg	Mn	Na	SO_4
2515 PATUXENT RIVER HOWARD MD 391417 770323 SANDY SPRING 112m 80/12/30 ***m 12m BR2 S5 DIST3 RAINpH: 4.3 1067mm	0	0	6.8	6.59	263	227	76	39	338	208	2	71	197	0.0	124	61
2516 HAWKINS RIVER MONTGOMERY MD 391026 770120 SANDY SPRING 94m 80/12/30 ***m 7m BR2 S5 DIST4 RAINpH: 4.3 1067mm	0	0	6.6	6.68	370	338	98	39	301	319	3	68	172	0.0	126	182
2517 GILBERT CREEK CHARLES MD 383045 764828 HUGHESVILLE 33m 80/12/30 ***m 3m BR2 S3 DIST3 RAINpH: 4.4 1016mm	0	4	6.4	6.77	194	171	98	45	473	211	5	60	320	0.0	109	464
2518 TRINITY CHURCH RUN CHARLES MD 382719 765109 CHARLOTTE HALL 15m 81/12/30 ***m 3m BR4 S3 DIST3 RAINpH: 4.4 1016mm	0	5	6.4	6.61	333	301	99	53	472	163	4	46	364	0.0	91	408
2519 TRIB TO OCTORARO CRE CECIL MD 394110 760820 CONOWINGO DAM 33m 81/ 6/ 1 ***m 3m BR2 S5 DIST4 RAINpH: 4.3 1118mm	0	16	7.3	8.00	682	848	148	134	282	266	5	75	558	1.4	296	300
2520 LAKE KOSHARE GARRETT MD 392705 792820 OAKLAND 731m 81/ 2/17 1.5m 4ha BR3 S3 DIST3 RAINpH: 4.3 1321mm	0	0	5.2	6.57	31	5	38	49	188	31	3	51	136	0.0	100	232
	2	2	5.5	6.35	624	596	35	71	218	59	3	****	232	0.0	68	271
2521 PLUM CREEK CECIL MD 393405 755310 NORTH EAST 3m 81/ 6/ 1 ***m 5m BR2 S3 DIST3 RAINpH: 4.3 1118mm	0	17	5.4	4.83	20	-5	42	99	38	100	5	65	68	7.6	30	189
2522 CYPRESS BRANCH KENT MD 391525 755000 MILLINGTON 3m 81/ 6/ 1 ***m 5m BR4 S3 DIST3 RAINpH: 4.4 1118mm	0	22	6.7	7.06	358	313	88	115	138	300	70	72	255	5.8	122	199
2523 WILLISTON LAKE CAROLINE MD 384940 755030 HOBBS 3m 81/ 6/ 1 1.2m 13ha BR2 S3 DIST4 RAINpH: 4.5 1118mm	0	23	7.6	7.53	304	279	86	29	251	277	40	35	224	1.7	55	179
	3	20	6.9	6.61	313	279	91	59	168	279	37	51	235	1.2	80	137

	D	T	FLD pH	LAB pH	FEP ALK	DEP ALK	COND	Al	Ca	Cl	CLR	K	Mg	Mn	Na	SO_4
2524 HIGGINS MILLPOND DORCHESTER MD 383110 755745 EAST NEW MARKET 2m 81/ 6/ 1 0.3m 63ha BR2 S5 DIST4 RAINpH: 4.5 1168mm																
	0	24	7.2	6.99	465	416	120	78	210	417	100	59	319	1.7	129	268
	2	24	7.1	6.92	441	397	117	75	213	359	100	57	306	3.4	123	265
2525 ADKINS POND WICOMICO MD 382000 752230 WANGO 9m 81/ 6/ 1 0.5m 9ha BR2 S4 DIST4 RAINpH: 4.5 1219mm																
	0	20	6.6	6.42	338	298	106	70	134	329	70	55	191	1.4	71	242
	2	17	6.4	7.30	441	392	104	33	189	343	60	38	188	1.7	48	182
2603 BURCHES RUN MARSHALL WV 395835 803745 MOUNDSVILLE 235m 81/ 3/19 ***m 5m BR3 S4 DIST3 RAINpH: 4.2 1067mm																
	0	2	7.2	7.98	1377	1338	250	0	1969	132	3	10	515	2.5	36	927
2604 CONAWAY LAKE TYLER WV 392520 805130 SHIRLEY 231m 81/ 3/19 1.8m 1ha BR3 S4 DIST4 RAINpH: 4.2 1118mm																
	0	2	7.0	7.28	441	402	137	20	318	87	6	29	248	2.3	52	452
	8	3	6.8	6.95	431	397	83	18	352	63	5	28	260	2.5	51	450
2610 EAST LYNN LAKE WAYNE WV 380440 822306 WAYNE 196m 81/ 3/20 0.7m 430ha BR3 S3 DIST4 RAINpH: 4.3 1118mm																
	0	4	6.5	7.27	142	118	57	259	71	47	3	108	194	3.4	149	395
	8	4	6.7	7.00	137	103	60	261	71	73	4	105	192	4.0	145	417
2612 HORSE CREEK LAKE WYOMING WV 373425 814235 BAILEYSVILLE 355m 81/ 3/20 0.5m 5ha BR2 S3 DIST2 RAINpH: 4.4 1118mm																
	0	3	6.7	6.95	191	147	76	182	78	18	1	89	178	2.6	111	435
	6	3	6.8	7.70	206	166	76	44	43	25	0	42	48	1.3	15	439
2613 PLUM ORCHARD LAKE FAYETTE WV 375700 811435 OAK HILL 528m 81/ 3/21 4.0m 77ha BR2 S3 DIST3 RAINpH: 4.4 1168mm																
	0	4	6.8	7.00	167	138	45	134	77	20	3	77	154	1.5	82	318
	8	3	6.8	6.79	167	143	51	109	93	36	3	68	150	1.7	75	329
2614 MONCOVE LAKE MONROE WV 373733 802107 PAINT BANK 763m 81/ 3/21 1.5m 39ha BR4 S3 DIST3 RAINpH: 4.4 1041mm																
	0	2	6.7	6.81	147	113	33	37	74	65	6	39	76	1.3	21	127
	6	2	6.8	6.54	142	108	30	37	79	95	5	36	80	1.3	21	127

	D	T	FLD pH	LAB pH	FEP ALK	DEP ALK	COND	Al	Ca	Cl	CLR	K	Mg	Mn	Na	SO_4
2615 SHERWOOD LAKE GREENBRIER WV 380010 800030 LAKE SHERWOOD 813m 81/ 3/21 1.0m 69ha BR2 S3 DIST3 RAINpH: 4.4 1016mm																
	0	3	6.8	6.25	78	39	20	52	36	35	3	48	46	3.1	15	67
	5	3	6.8	6.72	103	73	20	0	65	29	5	10	17	1.9	1	65
2616 SPRUCE KNOB LAKE RANDOLPH WV 384210 793515 SPRUCE KNOB 1171m 81/ 7/11 1.0m 11ha BR2 S3 DIST3 RAINpH: 4.3 1016mm																
	0	25	7.5	7.34	165	143	27	4	154	7	10	13	54	2.3	5	41
	5	16	6.5	6.44	401	356	45	9	133	5	8	20	72	29.5	10	15
2619 TETER CREEK LAKE BARBOUR WV 390625 795230 MONTROSE 560m 81/ 3/22 1.5m 13ha BR3 S3 DIST3 RAINpH: 4.3 1321mm																
	0	3	6.6	6.70	60	14	35	78	53	14	1	58	82	2.0	32	156
	5	3	6.6	6.58	65	19	31	66	48	25	1	54	69	1.9	26	182
2621 LITTLE RACCOON CREEK PRESTON WV 392235 795010 NEWBURG 424m 81/ 3/22 ***m 4m BR3 S3 DIST1 RAINpH: 4.4 1270mm																
	0	3	7.1	7.26	255	206	59	7	274	258	3	17	125	1.3	15	333
2622 LAKE O' WOODS PRESTON WV 394205 794355 BRUCETON MILLS 571m 81/ 3/22 ***m 20ha BR3 S3 DIST4 RAINpH: 4.3 1219mm																
	0	2	7.1	6.37	270	250	71	0	396	41	0	9	105	1.5	7	318
2623 N BR SNOWY CREEK PRESTON WV 392715 793100 TERRA ALTA 777m 81/ 3/22 ***m 6m BR3 S3 DIST3 RAINpH: 4.3 1321mm																
	0	3	7.0	6.30	83	63	50	17	80	44	0	27	59	0.9	11	261
2624 STONEY RIVER LAKE GRANT WV 390812 791755 MOUNT STORM 1035m 81/ 7/11 3.7m 165ha BR3 S5 DIST2 RAINpH: 4.3 1118mm																
	0	23	5.0	5.10	18	-9	22	19	47	13	3	28	35	2.6	6	67
	9	18	5.1	4.84	18	-9	23	23	44	10	5	32	35	2.8	7	88
2627 CACAPON PARK LAKE MORGAN WV 393000 781805 RIDGE 311m 81/ 7/11 2.8m 2ha BR2 S5 DIST3 RAINpH: 4.3 914mm																
	0	26	7.2	6.00	977	941	116	3	946	34	3	12	313	3.9	27	111
	5	15	6.9	7.31	1274	1140	131	0	1026	31	5	11	285	36.6	21	72

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                                                FLD  LAB    FEP   DEP
                                          D  T  pH   pH     ALK   ALK  COND  Al    Ca    Cl  CLR   K    Mg  Mn    Na   SO4
2628 WARDEN LAKE           HARDY       WV
     390755 783550 YELLOW SPRING   392m
     81/ 7/11  3.3m    18ha  BR3 S5
     DIST3  RAINpH: 4.3   914mm
                                          0 27  8.6  8.39   670   606    94   7   716    18   2    18   334  0.5  42   184
                                          6 18  7.3  7.30  1688  1615   185   0  1553    15   8    11   435 48.5  33    67

2630 WIGNER RUN            RITCHIE     WV
     390455 810440 SMITHVILLE      210m
     81/ 3/19  ***m     4m   BR3 S5
     DIST3  RAINpH: 4.2  1219mm
                                          0  2  7.1  7.71   465   432   112  14   202   166   3    25   126  0.0  22   429

2632 RT FK BUFFALO CREEK  LOGAN        WV
     375335 820040 CHAPMANVILLE    213m
     81/ 3/20  ***m     3m   BR2 S3
     DIST3  RAINpH: 4.4  1118mm
                                          0  4  6.7  6.43   134    78   136 120   257    24   0    74   498  0.5 246   856

2633 STEPHENS LAKE         RALEIGH     WV
     374640 811830 ECCLES          617m
     81/ 3/20  4.0m    93ha  BR2 S3
     DIST3  RAINpH: 4.4  1168mm
                                          0  3  6.7  6.72   109    78    33  64    61    34   1    53    87  3.2  32   212
                                         12  3  6.7  7.00   137   107    32  36    62    39   4    39    68  2.7  18   202

2634 PANTHER CREEK         NICHOLAS    WV
     381325 803940 NETTIE          677m
     81/ 3/21  ***m     3m   BR2 S3
     DIST3  RAINpH: 4.4  1219mm
                                          0  2  6.7  7.62   274   235   230   4   439  1433   3    13   155  0.0  13   225

2635 BIG DITCH LAKE        WEBSTER     WV
     382410 803400 COWEN           677m
     81/ 3/21  1.0m     4m   BR2 S3
     DIST4  RAINpH: 4.4  1244mm
                                          0  1  6.8  6.58   142   108    43  12   109   125   8    23    65  1.7  11   137
                                          5  2  6.7  7.95   166   118   111  11   111   625   9    22    64  1.3  10    94

2636 PICKLES FORK RESERV   BRAXTON     WV
     384550 803555 ORLANDO         259m
     81/ 3/22  ***m     4ha  BR3 S3
     DIST3  RAINpH: 4.4  1219mm
                                          0  1  7.1  8.31   548   515   104   9   290    47   8    20   155  1.3  21   377

2637 STONECOAL LAKE        LEWIS       WV
     385845 802250 ROANOKE         344m
     81/ 3/22  1.0m   239ha  BR3 S5
     DIST4  RAINpH: 4.3  1219mm
                                          0  3  6.9  7.58   490   456   113   4   296   187   8    14   104  0.9  19   523
                                          3  3  7.0  7.45   534   495   118   9   263   158   8    19   139  0.9  19   516

2640 UPPER GLADE CR RESER RALEIGH      WV
     374020 810345 SHADY SPRING    823m
     81/ 4/25  ***m    33ha  BR2 S3
     DIST3  RAINpH: 4.4  1119mm
                                          0 12  6.5  7.07   113    73    95  56    70   612   0    50    91  1.5  31   207
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                                             FLD  LAB   FEP    DEP
                                      D   T  pH   pH    ALK    ALK  COND   Al     Ca     Cl CLR    K      Mg  Mn    Na     SO4
2701 PEACEFUL VALLEY LAKE FREDRICK   VA
     390840 782145 HAYFIELD        259m
     81/ 4/24  1.5m    7ha  BR2 S3
     DIST3  RAINpH: 4.3   914mm
                                      0  15  7.9  8.68  975    936   111    0   1439     33   3     7     269  0.9  13    228
                                      5  15  7.7  8.36 1146   1117   147    0   1364     44   5     8     295  3.3  16    273

2702 MILL CREEK           SHENANDOAH VA
     384520 784015 CONICVILLE      281m
     81/ 4/24  ***m    7m   BR2 S3
     DIST4  RAINpH: 4.3   914mm
                                      0  16  8.1  7.58 1994   1940   242   16   2625    199   5    26    1601  0.0 326    249

2703 DRY RUN              ROCKINGHAM VA
     382440 783313 ELKTON EAST     415m
     81/ 4/24  ***m    4m   BR4 S3
     DIST4  RAINpH: 4.4  1316mm
                                      0  13  7.3  8.49  387    356    52   57     84     25   3    46     111  0.0  38     52

2704 LAKE ALBEMARLE       ALBEMARLE  VA
     380525 783743 CROZET          152m
     81/ 4/24  1.5m   17ha  BR2 S3
     DIST3  RAINpH: 4.4  1016mm
                                      0  18  7.5  8.43  338    313    53   16    124    106   6    26      86  0.3  16     52
                                      6  10  6.7  7.08  338    289    54   25    105     99   6    32      89  1.4  20     57

2705 FLUVANNA RURITAN LAK FLUVANNA   VA
     375325 782225 BOYD TAVERN     116m
     81/ 4/24  3.0m   23ha  BR2 S3
     DIST3  RAINpH: 4.5  1168mm
                                      0  18  7.4  8.68  252    224    33  181     43     52   6    91     105  0.0  63     62
                                      7  11  6.8  7.16  299    279    32  181     45     58   5    87     106  1.1  65     46

2706 HOLIDAY LAKE         APPOMATTOX VA
     372330 783823 HOLIDAY LAKE    136m
     81/ 4/24  1.0m   38ha  BR1 S3
     DIST4  RAINpH: 4.5  1143mm
                                      0  17  7.4  8.77  304    269    43  143     59     47   5    79     121  0.3  65     62
                                      5  14  7.1  8.42  343    318    45  192     51     53   6    41     123  1.3  92     62

2707 UNNAMED CREEK        AMHERST    VA
     373235 790345 AMHERST         215m
     81/ 4/24  ***m    3m   BR1 S3
     DIST4  RAINpH: 4.5  1118mm
                                      0  13  7.3  8.13  554    529    61  148     77     73   5    78     157  0.5  66     40

2708 COL SULPH SPR BR RES ROCKBRIDGE VA
     375830 793113 MILLBORO        440m
     81/ 5/13  2.3m    4ha  BR4 S3
     DIST2  RAINpH: 4.5  1016mm
                                      0  19  7.1  7.53  162    127    34  233     48     18   4   131     125  1.9  85    158
                                      3  16  7.1  7.39  176    147    14  241     48     29   3   133     122  2.5  85    168
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                                        FLD  LAB   FEP   DEP
                               D  T     pH   pH    ALK   ALK  COND  Al    Ca    Cl CLR    K    Mg  Mn   Na   SO4
2709 MOUNTAIN LAKE       GILES      VA
     372135 803213 EGGLESTON    1162m
     81/ 4/25  6.0m   22ha  BR4 S3
     DIST4  RAINpH: 4.5  1016mm
                               0  8   6.6  8.33  186   157   27    8    65    13  3    19    32 0.0    4    41
                               9  6   6.8  6.91  109    88   21   10    88    17  3    21    49 0.0    7    89

2710 MUDDY FORK  CREEK   TAZEWELL   VA
     371530 812015 BRAMWELL      714m
     81/ 4/25  ***m    3m   BR4 S3
     DIST4  RAINpH: 4.5  1118mm
                               0 10   6.9  8.33  333   294   51   21   130    43  0    30   101 0.9   21   195

2711 HUNGRY MOTHER LAKE  SMYTH      VA
     365215 813125 MARION       671m
     81/ 4/25  1.0m   40ha  BR2 S3
     DIST4  RAINpH: 4.5  1169mm
                               0 14   6.6  8.26  294   264   53  111    92    57  3    71   164 0.9   79   117
                               6 13   6.9  8.53  273   240   51  102    84    89  3    68   143 0.8   68   106

2712 CLEAR CREEK LAKE    WASHINGTON VA
     363950 829723 WYNDALE       641m
     81/ 4/25  1.0m   20ha  BR4 S3
     DIST3  RAINpH: 4.5  1168mm
                               0 17   8.2  8.37 3003  2935  368   25  2011    25  1    33  1811 2.2  424   405
                               4 15   8.4  8.36 3209  3092  338   23  2094    44  1    32  1764 2.3  392   413

2713 CABIN CREEK         GRAYSON    VA
     363620 811120 PARK         1025m
     81/ 4/25  ***m    4m   BR2 S3
     DIST3  RAINpH: 4.5  1219mm
                               0  8   6.5  6.87   88    59   21   43    31    15  4    43    36 0.0   11    67

2715 SWAN LAKE           PITTSYLVAN VA
     364215 792010 BLAIRS        198m
     81/ 4/26  0.5m    5ha  BR1 S4
     DIST4  RAINpH: 4.5  1118mm
                               0 15   6.9  7.46  402   353   60  258    77   116  8   106   213 2.6  162   137
                               4  9   6.6  6.74  392   339   71  259    64   102  6   106   181 8.5  134   143

2716 CONNER LAKE         HALIFAX    VA
     365520 784810 CONNER LAKE   113m
     81/ 4/26  0.2m   41ha  BR1 S3
     DIST4  RAINpH: 4.5  1118mm
                               0 17   7.0  8.03  460   421   69  104    87    92  3    66   155 4.6   73   252
                               3 15   6.9  7.83  510  1019   69  145    73    71  3    78   155 5.6   85   238

2717 SLAGLES LAKE        GREENSVILL VA
     364445 773140 EMPORIA        36m
     81/ 4/26  2.0m   58ha  BR3 S3
     DIST3  RAINpH: 4.6  1118mm
                               0 18   7.2  8.16  510   470   90   52   163   145 18    47   200 1.3   66   333
                               3 18   7.3  8.09  510   470   84   56    93   124 18    50   120 0.9   43   340
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	D	T	FLD pH	LAB pH	FEP ALK	DEP ALK	COND	Al	Ca	Cl	CLR	K	Mg	Mn	Na	SO$_4$
2718 LAKE PRINCE ISLE OF WI VA 364830 764105 WINDSOR 6m H1/ 4/26 ***m 5ha BR4 S3 DIST2 RAINpH: 4.6 1118mm	0	17	6.8	7.14	354	325	121	5	391	321	30	15	163	1.9	17	477
2719 TURKEY ISLAND CREEK CHARLES CI VA 372307 771409 ROXBURY 3m H1/ 4/26 ***m 4m BR3 S4 DIST3 RAINpH: 4.6 1113mm	0	17	6.9	7.33	499	442	72	3	372	161	15	10	97	4.5	6	67
2720 RESER ON LICKING CK CHESTERFIE VA 372113 773230 BEACH 49m H1/ 4/26 4.0m 45ha BR3 S3 DIST3 RAINpH: 4.6 1116mm	0	19	6.8	7.76	142	108	43	105	49	88	3	68	87	1.3	41	215
	5	17	6.7	6.96	147	118	39	93	52	63	0	63	85	1.5	47	219
2721 REEDY MILLPOND CAROLINE VA 375545 771810 PENOLA 20m H1/ 4/26 3.0m 19ha BR2 S4 DIST4 RAINpH: 4.5 1143mm	0	20	5.9	6.39	93	61	33	165	31	68	22	83	67	2.1	39	100
	2	16	5.9	6.12	73	39	33	166	29	118	25	95	64	2.2	39	68
2722 GRANT LAKE SPOTSYLVAN VA 381835 774350 CHANCELLORSVIL 103m H1/ 4/27 2.3m 9ha BR2 S3 DIST3 RAINpH: 4.5 1067mm	0	16	6.6	7.40	141	162	33	343	24	31	5	121	77	1.9	66	78
	4	13	6.6	6.98	172	145	33	335	25	42	3	122	61	2.4	65	106
2723 NIGGER RUN CULPEPER VA 384615 775515 JEFFERSONTON 110m H1/ 4/27 ***m 3m BR3 S3 DIST4 RAINpH: 4.3 1067mm	0	14	6.9	7.03	416	397	75	41	143	161	3	42	162	2.3	46	127
2724 N FK CATOCTIN CREEK LOUDOUN VA 391145 774525 ROUND HILL 177m H1/ 4/27 ***m 2m BR3 S3 DIST4 RAINpH: 4.3 1016mm	0	17	7.3	7.63	329	309	74	162	110	71	8	35	248	0.9	142	182
2725 BRIGGS LAKE POWHATAN VA 373455 775413 GOOCHLAND 48m H1/ 4/27 ***m 5ha BR2 S3 DIST4 RAINpH: 4.5 1118mm	0	18	6.6	6.35	301	278	46	76	98	53	4	57	143	7.1	57	148

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                                                 FLD  LAB   FEP    DEP
                                          D  T   pH   pH    ALK    ALK   COND   Al     Ca     Cl CLR     K     Mg  Mn    Na    SO4
2801 BROOKS LAKE           GUILFORD    NC
     361353 794338 BROWN'S SUMMIT 228m
     81/ 5/13  2.0m    13ha  BR2 S3
     DIST2  RAINpH: 4.6  1143mm
                                          0  23  8.1  8.78  485    445    56    53    107     68   5     46    136  1.2  44     89
                                          3  21  7.8  8.49  475    446    52    48    120     60   5     44    139  1.9  45    101

2802 ROCK CREEK            WILKES      NC
     361220 810435 ROARING RIVER   311m
     81/ 5/13  ***m     5m   BR2 S3
     DIST4  RAINpH: 4.5  1219mm
                                          0  18  7.2  7.04  176    210    30    34     57     58   5     40     61  1.2  16     23

2803 PRICE LAKE            WATAUGA     NC
     360816 814350 BOONE          1025m
     81/ 5/14  1.0m     9ha  BR2 S3
     DIST2  RAINpH: 4.5  1321mm
                                          0  16  6.7  6.92  103     69    19    16     42     31   9     27     29  1.5   5     62
                                          6  14  6.4  7.33  348    328    23    17     47     34  10     27     34  1.9   6     40

2804 QUEEN'S CREEK         MACON       NC
     351635 833745 HEWITT          964m
     81/ 5/16  ***m     3m   BR2 S3
     DIST3  RAINpH: 4.5  1626mm
                                          0  17  7.2  7.78  152    122    35    49     25     29   4     45     30  1.3   9     18

2805 LAKE LOGAN            HAYWOOD     NC
     352530 825535 WAYNESVILLE     887m
     81/ 5/16  2.0m    35ha  BR2 S3
     DIST3  RAINpH: 4.5  1422mm
                                          0  16  6.5  7.00   83     54    16    37     22      7   8     39     23  1.3   6     35
                                          4  16  7.0  6.34   35     69    18    48     21     18   4     46     25  1.3   7     46

2806 MORGAN LAKE           McDOWELL    NC
     354330 820330 MARION          427m
     81/ 5/16  1.0m    10ha  BR2 S3
     DIST0  RAINpH: 4.5  1321mm
                                          0  19  7.5  7.47  166    215    34    52     40     31   5     47     51  1.7  17     41
                                          2  17  8.5  8.48  235    201    30    51     47     34   5     47     56  2.0  19     35

2807 RESER ON MAIDEN CREE CATAWBA      NC
     353505 811135 MAIDEN          257m
     81/ 5/17  1.3m     9ha  BR2 S3
     DIST3  RAINpH: 4.5  1168mm
                                          0  20  6.9  7.17  220    191    28    13    107     63   3     23     64  1.5  10     46
                                          5  15  6.2  6.39  313    299    37    80     61     60   3     58     96 12.5  39     41

2808 LAKE LYNN             CABARRUS    NC
     352400 803129 CONCORD         174m
     81/ 5/17  2.0m     6ha  BR1 S4
     DIST4  RAINpH: 4.6  1219mm
                                          0  22  7.6  7.67  656    622   107    16    431    197   5     27    306  2.0  56    253
                                          7  14  6.8  [illegible]  975    336   122    17    427    195   8     28    296 58.8  56    106
```

	D	T	FLD pH	LAB pH	FEP ALK	DEP ALK	COND	Al	Ca	Cl	CLR	K	Mg	Mn	Na	SO_4
2809 DENNISON'S CREEK MONTGOMERY NC 352320 795205 STAR(TROY 15') 137m 81/ 5/17 ***m 8m BR3 S3 DIST3 RAINpH: 4.6 1118mm																
	0	20	6.9	7.31	416	387	49	17	125	60	16	27	88	2.7	17	23
2810 UNIVERSITY LAKE ORANGE NC 355347 790539 CHAPEL HILL 105m 81/ 5/18 1.0m 70ha BR3 S5 DIST4 RAINpH: 4.6 1118mm																
	0	22	7.5	7.97	559	519	85	14	321	176	6	25	204	2.9	36	132
	4	20	6.9	6.77	612	568	90	15	334	124	8	25	219	8.8	38	137
2901 DAVY CROCKETT LAKE GREENE TN 360426 825130 DAVY CROCKETT 379m 81/ 5/14 0.8m 255ha BR4 S3 DIST3 RAINpH: 4.5 1118mm																
	0	19	7.6	7.30	867	823	97	5	602	60	3	15	250	1.0	26	117
	3	19	7.7	7.85	882	842	102	0	624	63	5	10	180	1.3	10	101
2902 PRESSMEN'S HOME LAKE HAWKINS TN 362705 830305 CAMELOT 412m 81/ 5/14 3.0m 7ha BR4 S4 DIST4 RAINpH: 4.5 1118mm																
	0	22	7.9	8.58	485	450	93	9	324	87	3	19	167	0.4	24	390
	6	18	7.0	6.94	485	451	91	9	307	79	6	20	166	0.7	23	411
2903 BULLRUN CREEK UNION TN 361044 835247 BIG RIDGE PARK 299m 81/ 5/14 ***m 6m BR4 S4 DIST3 RAINpH: 4.5 1168mm																
	0	19	8.1	6.97	1901	1842	245	4	2677	100	3	13	974	3.0	96	158
2904 RES ON N F PINE CREE SCOTT TN 363030 843225 ONEIDA NORTH 442m 81/ 5/15 2.0m 16ha BR2 S3 DIST3 RAINpH: 4.5 1321mm																
	0	17	6.7	7.22	108	78	99	8	348	58	3	19	179	47.2	24	767
	3	15	6.7	7.30	137	117	96	5	438	55	3	15	179	45.4	19	737
2905 CITY LAKE ON CARR CK OVERTON TN 362040 851950 OKALONA 284m 81/ 5/15 3.0m 15ha BR4 S3 DIST4 RAINpH: 4.5 1346mm																
	0	16	8.7	7.12	1249	1205	191	0	1816	102	5	8	395	1.7	21	67
	4	15	9.3	7.01	1327	1283	188	0	1749	116	3	3	182	3.5	4	52
2906 BURGESS FALLS LAKE PUTNAM TN 360235 853530 BURGESS FALLS 269m 81/ 5/15 0.5m 20ha BR4 S3 DIST3 RAINpH: 4.5 1321mm																
	0	16	8.8	7.46	1675	1142	230	0	2085	203	3	8	487	2.0	29	216
	4	16	9.0	7.57	2140	2121	245	0	2075	215	3	9	510	2.4	32	232

	D	T	FLD pH	LAB pH	FEP ALK	DEP ALK	COND	Al	Ca	Cl	CLR	K	Mg	Mn	Na	SO_4
2907 FALLS CREEK LAKE VAN BUREN TN 353940 852145 SAMPSON 508m 81/ 5/15 3.0m 81ha BR2 S3 DIST3 RAINpH: 4.5 1372mm																
	0	16	7.8	6.86	49	24	20	11	71	25	3	21	41	0.6	6	111
	7	15	7.2	6.49	73	49	18	17	57	31	3	27	42	1.1	7	84
2908 HUNGERS POND MEIGS TN 352020 845805 BIRCHWOOD 235m 81/ 5/15 0.5m 9ha BR4 S4 DIST3 RAINpH: 4.5 1321mm																
	0	19	8.2	7.50	118	88	27	3	137	63	8	12	44	1.5	4	67
	2	19	7.1	6.76	73	9	29	3	132	29	8	13	43	1.7	4	94
2909 QUARRY CREEK MONROE TN 352125 841637 TELLICO PLAINS 262m 81/ 5/16 ***m 3m BR2 S3 DIST2 RAINpH: 4.5 1321mm																
	0	14	7.5	8.51	353	313	56	83	101	60	3	60	160	0.6	65	191
2910 LAMBERT LAKE BLOUNT TN 353933 635705 BLOCKHOUSE 326m 81/ 5/16 2.5m 8ha BR4 S3 DIST2 RAINpH: 4.5 1321mm																
	0	19	7.2	8.81	245	215	29	22	90	5	3	31	74	0.0	16	57
	9	14	6.4	6.61	294	259	33	13	133	10	3	23	80	4.7	12	46
2911 TRIB SIXMILE CREEK BLOUNT TN 353855 835750 BLOCKHOUSE 296m 81/ 5/16 ***m 2m BR4 S3 DIST3 RAINpH: 4.5 1321mm																
	0	12	7.6	7.51	780	764	88	0	613	2	5	9	154	0.5	9	208

APPENDIX B. HISTORICAL DATA

The historical listing can be separated by state according to the following code, which appears in the second column of each entry, i.e., the second digit of the station code number:

1. New York
2. New Jersey
3. Pennsylvania
4. Delaware
5. Maryland
6. West Virginia
7. Virginia
8. North Carolina
9. Tennessee

Further information on the specific waters can be found in Appendix A.

Key to column headings for Appendix B:

1-4	station numbers (see above)
6-27	water body name
29-36	date (year, month, day) of historical sample
40	depth sample taken
43-45	pH of sample
47	method code for pH: 1=electrometric, 2=colorimetric
50-53	alkalinity of sample
55	method code for alkalinity: 1=fixed endpoint, 2=double endpoint
58-59	temperature at sample depth (°C)

A large number of cooperators in state agencies and other sources provided the historical data; some of these did not want themselves or their data specifically identified. Specific queries concerning data for particular waters will be accepted and passed on by the authors to the appropriate source.

STATN NAME	YR MO DA	Z	PH	M1	ALK	M2	TEM
2101 CAYUTA LAKE	37/ 7/19	0	8.3	2	980	1	••
	37/ 7/19	7	6.9	2	1332	1	••
2104 CASE LAKE	55/ 5/10	0	5.6	2	••••	•	••
	55/ 5/11	3	5.4	2	••••	•	••
	66/ 7/26	0	4.3	1	0	1	••
	66/ 7/26	2	4.9	2	0	1	••
	79/ 8/20	1	4.2	1	0	1	••
	80/ 9/17	1	4.6	1	0	1	••
2111 CLEAR LAKE	77/ 9/28	8	7.5	2	1920	1	••
2117 HEMLOCK LAKE	62/10/ 3	9	8.2	1	1200	1	••
	66/ 5/10	9	7.4	1	1000	1	••
	75/ 8/28	9	7.8	1	1106	1	••
	80/ 9/22	9	7.4	1	1080	1	••
	81/ 2/25	0	7.2	1	••••	•	••
2124 ECHO LAKE	39/ 8/••	0	8.2	2	1128	1	••
	39/ 8/••	3	6.9	2	1300	1	••
	49/ 8/••	0	8.4	2	1680	1	••
	49/ 8/••	3	8.2	2	1540	1	••
2125 CATSPAW LAKE	66/ 8/••	0	6.8	2	••••	•	••
	66/ 8/••	1	6.8	2	208	1	••
2126 SEARS POND	76/ 8/••	0	7.3	2	560	1	••
2129 LAKE OF THE WOODS	70/ 7/••	0	7.4	2	680	1	••
	70/ 7/••	22	7.2	2	680	1	••
2135 NEWPORT POND	32/ 8/18	8	6.2	2	6	1	••
	32/ 8/18	0	6.6	2	154	1	••
	56/ 6/25	0	6.4	2	••••	•	••
	56/ 6/25	12	5.8	2	••••	•	••
	71/ 7/ 6	0	6.9	2	160	1	••
	71/ 7/ 6	9	6.3	2	260	1	••
	79/ 8/22	1	6.5	1	163	1	••
2137 CRYSTAL LAKE	32/ 8/ 5	14	6.2	2	380	1	••
	32/ 8/ 5	0	6.8	2	360	1	••
2140 DUCK POND	30/ 9/ 7	0	5.8	2	140	1	••
	30/ 9/ 7	2	5.8	2	140	1	••

STATN NAME	YR MO DA	Z	PH	M1	ALK	M2	TEM
2143 BALFOUR LAKE	32/ 9/ 7	14	6.0	2	400	1	••
	32/ 9/ 7	0	6.4	2	100	1	••
	56/ 8/28	6	6.6	2	••••	•	••
	56/ 8/28	12	6.2	2	••••	•	••
	64/ 6/22	0	6.8	2	180	1	••
	64/ 6/22	12	6.4	2	190	1	••
	68/ 7/30	0	6.1	2	800	1	••
	68/ 7/30	12	5.6	2	1000	1	••
	78/ 7/25	0	•••	•	188	2	••
	78/ 7/31	0	7.5	1	••••	•	••
	79/ 8/29	1	6.3	1	67	2	••
2146 CATAMOUNT POND	30/ 9/ 9	1	5.8	2	0	1	••
	30/ 9/ 9	0	5.8	2	100	1	••
	30/ 9/ 9	3	5.8	2	160	1	••
	55/ 5/26	2	5.2	2	••••	•	••
	55/ 5/26	8	6.2	2	••••	•	••
	79/ 8/20	1	4.0	1	0	2	••
2147 ROCK LAKE	32/ 8/29	2	6.8	2	200	1	••
2148 G LAKE	34/ 8/11	8	6.0	2	228	1	••
	34/ 8/11	8	6.7	2	168	1	••
	75/ 6/24	0	5.6	1	5	2	••
	78/ 7/25	0	5.2	1	••••	•	••
	78/ 7/25	9	4.8	1	••••	•	••
	81/ 7/ 2	0	5.7	1	13	2	••
	81/ 7/ 2	8	6.1	1	21	2	••
2151 BOND LAKE	70/10/ 3	9	8.5	2	200	1	••
2191 CRYSTAL LAKE	35/ 7/ 5	0	7.6	2	256	1	24
	35/ 7/ 5	7	6.0	2	408	1	15
	64/ 7/21	1	6.5	2	••••	•	26
	64/ 7/21	6	6.5	2	••••	•	12
2193 KLEINE KILL LAKE	32/ 7/18	0	8.3	2	••••	•	••
	38/ 3/ 5	0	7.0	2	••••	•	••
	38/ 7/30	0	7.0	2	••••	•	••
	39/ 3/ 3	0	7.2	2	••••	•	••
	75/12/ 2	0	7.2	2	••••	•	••
	76/ 5/23	0	7.2	2	••••	•	••
	76/ 6/19	0	•••	•	1360	1	••
	77/ 3/30	0	6.6	2	••••	•	••
	77/10/ 8	0	6.8	2	••••	•	••
	78/ 4/27	0	7.0	2	••••	•	••
	79/ 4/20	0	7.1	2	••••	•	••
	80/ 4/16	0	7.2	2	••••	•	••
	81/10/16	0	7.2	2	••••	•	••

STATN NAME	YR MO DA	Z	PH	M1	ALK	M2	TEM
2194 NORTH LAKE	36/ 6/24	0	6.2	2	150	1	**
	36/ 6/24	1	6.2	2	80	1	**
	57/ 7/15	0	6.0	2	****	*	**
	57/ 7/15	2	6.0	2	****	*	**
	71/ 7/19	0	6.8	2	684	1	**
	71/ 7/19	2	6.8	2	684	1	**
2195 ALDER LAKE	80/ 7/ 9	0	7.2	2	280	1	20
	80/ 7/ 9	5	6.5	2	400	1	16
2197 TUNIS LAKE	73/ 4/19	0	7.2	2	400	1	**
	73/ 4/19	2	6.4	2	400	1	**
2201 LAKE GENEVIEVE	77/ 4/ 5	0	8.0	1	2800	1	9
2202 FAIRVIEW LAKE	75/12/10	0	6.2	1	260	1	4
	76/ 6/ 3	0	6.8	1	300	1	18
	77/ 5/ 5	0	6.9	1	240	1	13
	77/10/18	0	7.3	1	340	1	8
2203 ASHROE LAKE	76/ 3/24	0	6.5	1	380	1	8
2204 STEENYKILL LAKE	52/ 8/18	0	6.7	2	182	1	24
	52/ 8/18	4	6.3	2	200	1	22
	75/ 7/24	0	6.4	1	320	1	26
	76/11/ 3	0	6.7	1	400	1	9
	77/ 4/ 4	0	6.3	1	180	1	3
2207 SURPRISE LAKE	51/ 7/13	0	8.4	2	500	1	30
	51/ 7/13	1	8.3	2	560	1	19
2209 SUNSET LAKE	52/ 6/26	0	6.7	2	500	1	28
	52/ 6/26	3	6.6	2	480	1	19
2210 MOUNTAIN LAKE	50/**/**	0	8.3	2	1630	1	**
	50/**/**	**	7.1	2	1960	1	**
	75/ 8/20	0	8.6	1	2420	1	24
	76/12/ 8	0	8.1	1	2180	1	3
	77/ 4/ 5	0	8.0	1	1740	1	8
	79/ 3/27	0	7.2	1	1590	1	1
2211 LAKE SOLITUDE	51/ 8/ 7	3	7.1	2	1100	1	**
	51/ 8/ 7	0	7.4	2	1000	1	**
	51/ 8/ 7	0	7.4	2	1005	1	25
	51/ 8/ 7	3	7.1	2	1100	1	24
	72/ 2/ 3	0	7.7	1	1180	1	1
2211 LAKE SOLITUDE	72/ 7/31	0	7.3	1	1520	1	18
	73/ 1/ 3	0	7.4	1	3020	1	1
	73/ 7/10	0	7.2	1	1300	1	21
	74/ 1/ 8	0	7.5	1	900	1	1
	74/ 7/ 2	0	7.6	1	1080	1	17
	75/ 6/16	0	7.4	1	1160	1	19
	75/ 1/ 7	0	7.4	1	1120	1	2
	75/ 7/10	0	7.6	1	1580	1	18
	76/ 8/19	0	7.3	1	1360	1	17
	76/ 8/25	0	8.4	1	1860	1	24
	76/ 1/29	0	7.1	1	740	1	0
	76/ 7/19	0	9.9	1	1630	1	22
	77/ 8/25	0	7.3	1	860	1	15
2213 HAKIHOKAKE CREEK	78/ 9/20	0	7.8	1	780	1	18
	79/ 2/28	0	8.1	1	420	1	4
2216 PERRINEVILLE LAKE	78/ 6/21	0	7.0	1	240	1	26
2217 RED VALLEY LAKE	76/ 3/ 5	0	6.4	1	260	1	4
2218 JACKSONS MILLS LAKE	60/ 9/**	0	4.5	2	60	1	**
	75/10/ 2	0	4.8	1	100	1	18
	77/ 5/ 3	0	5.7	1	120	1	15
	77/ 7/**	0	4.9	1	****	*	**
	80/ 6/**	0	6.3	1	****	*	**
2219 BRISBANE LAKE	68/ 7/17	0	6.8	2	60	1	**
	69/ 8/12	3	6.6	2	****	*	**
	70/ 7/23	0	5.3	2	****	*	**
	78/ 5/21	0	5.8	1	100	1	23
	81/ 4/21	0	4.5	1	****	*	10
2220 SUCCESS LAKE	70/ 5/21	0	6.4	2	20	1	**
	75/ 4/30	0	4.3	1	120	1	12
	76/10/ 7	0	4.8	1	80	1	19
	77/ 6/28	0	4.5	1	60	1	27
	80/11/ 6	0	3.7	1	****	1	9
2221 PAMBER LAKE	76/11/ 9	0	4.7	1	120	1	5
	77/ 9/19	0	4.6	1	60	1	24
	78/ 6/19	0	4.6	1	120	1	24
	79/79/21	0	4.0	1	****	1	13

126.

STATN NAME	YR MO DA	Z	PH	M1	ALK	M2	TEM
2223 OYSTER CREEK	67/ 8/ 9	0	3.0	2	••••	•	••
	67/10/ 3	0	6.6	2	••••	•	••
	68/ 3/11	0	7.1	2	••••	•	••
	69/ 3/10	0	7.3	2	••••	•	••
	69/ 7/29	0	6.6	2	••••	•	••
	69/ 6/11	0	8.1	2	••••	•	••
	70/12/16	0	7.6	2	••••	•	••
	71/ 3/18	0	7.0	2	••••	•	••
	72/ 1/24	0	7.0	2	••••	•	••
	77/ 1/27	0	4.4	1	0	1	5
	77/ 7/22	0	4.7	1	100	1	18
	78/ 1/26	0	5.1	1	0	1	8
	78/ 6/29	0	4.5	1	0	1	23
2225 OSWEGO LAKE	52/ 8/ 1	0	4.3	2	••••	•	••
	52/ 8/ 1	••	4.3	2	0	1	••
	52/ 8/ 1	0	4.3	2	120	1	29
	52/ 9/ 1	2	4.3	2	0	1	25
	70/ 9/ 1	0	6.1	2	120	1	••
	70/ 9/ 1	••	6.0	2	120	1	••
	75/ 8/19	0	4.7	1	0	1	••
	75/ 8/18	0	4.2	1	90	1	22
	76/10/13	0	4.2	1	80	1	17
	77/ 5/12	0	4.3	1	40	1	12
	78/11/28	0	4.4	1	80	1	5
	81/ 2/23	0	4.6	1	••••	•	9
2226 ATSION LAKE	55/ 7/12	0	4.2	2	140	1	••
	55/ 7/12	••	4.2	2	••••	1	••
	55/ 7/27	0	4.5	2	380	1	••
	68/10/ 1	0	4.9	2	••••	•	••
	75/ 4/24	0	4.8	1	100	1	16
	76/10/ 5	0	5.2	1	80	1	17
	77/ 2/ 1	0	6.2	1	••••	•	3
	79/ 2/ 6	0	4.7	1	20	1	0
	81/ 8/19	0	3.7	1	0	1	••
2227 PARVIN LAKE	50/••/••	0	6.7	2	240	1	••
	50/••/••	••	6.6	2	160	1	••
	75/ 9/16	0	6.8	1	560	1	20
	76/ 4/ 5	0	6.4	1	300	1	11
	77/ 3/ 1	0	5.9	1	180	1	8
	78/ 7/26	0	7.0	1	380	1	26
	81/ 4/13	0	6.5	1	••••	•	13
2229 MASKELL MILLPOND	75/ 5/27	0	3.1	1	••••	1	29
	76/ 9/27	0	5.2	1	100	1	19
	77/12/ 7	0	4.5	1	100	1	5
2230 TUCKAHOE LAKE	73/ 7/20	0	5.2	2	60	1	••
	76/ 8/ 5	0	5.2	2	••••	•	••
	77/ 3/ 7	0	5.1	1	120	1	11
	81/ 4/23	0	5.0	1	••••	•	••
	81/ 9/16	0	4.7	1	200	1	••
	81/ 9/16	••	5.2	1	160	1	••
2303 CLEAR SHADE CREEK	79/ 5/10	0	6.6	1	240	1	••
	79/ 6/10	0	6.0	1	160	1	••
2305 LITTLE FISHING CREEK	72/ 1/17	0	7.0	1	200	1	••
	80/ 9/26	0	7.1	1	238	2	13
2306 LITTLE SANDY CREEK	81/ 3/24	0	7.0	1	580	1	••
2310 STRAIGHT RUN	75/ 7/10	0	7.6	1	800	1	17
2311 UPPER THREE RUNS	80/10/21	0	6.4	1	96	2	10
	80/ 8/ 6	0	6.2	1	80	1	••
	81/ 3/27	0	5.9	1	0	2	8
2313 RED RUN	81/ 7/16	0	7.7	1	9	2	25
	81/ 5/21	0	5.1	1	0	2	10
2330 N FORK TANGASCOOTACK C	66/ 8/17	0	6.6	1	280	1	••
2332 TROUT RUN	73/ 5/ 3	0	7.8	1	240	•	••
2333 SLATE RUN	81/ 7/24	0	7.6	1	5••	2	18
2335 COOKS RUN	78/ 7/20	0	6.7	1	240	•	••
	80/ 7/24	0	7.0	1	337	1	16
2354 GLADE RUN RESERVOIR	73/ 8/10	0	7.0	1	2000	1	••
2360 JORDON CREEK	66/ 9/ 8	0	7.2	2	5960	1	••
	72/ 1/26	0	7.5	1	800	1	••
	73/ 8/ 8	0	8.4	1	900	1	••
2362 CRABBY CREEK	71/11/ 3	0	6.6	2	1000	1	••

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STATN	NAME	YR MO DA	Z	PH	M1	ALK	M2	TEM
2363	VALLEY CREEK	72/11/21	0	8.2	1	3200	1	**
		72/10/ 3	0	7.8	2	1440	1	**
		74/ 8/20	0	8.6	1	3300	1	**
		75/ 6/19	0	8.3	1	3520	1	**
		76/ 3/ 1	0	8.4	1	3360	1	**
		78/ 7/12	0	8.5	1	3560	1	**
		78/ 9/27	0	7.1	2	1200	1	**
2364	PICKERING CREEK	74/ 9/27	0	7.7	2	920	1	15
		76/10/ 5	0	6.9	2	1200	1	**
		77/ 3/10	0	8.1	1	840	1	**
2365	MARSH CREEK LAKE	75/ 7/29	0	8.0	2	****	*	**
		75/ 7/29	9	6.4	2	****	*	**
		77/ 7/21	0	8.5	1	920	1	**
		77/ 7/21	9	6.9	1	1040	1	**
2369	LAUREL CREEK	75/10/21	0	6.6	1	100	1	**
2371	BRUSH CREEK	76/ 8/24	0	6.9	1	200	1	**
2374	ARCH SPRING	71/ 4/12	0	7.3	1	4560	1	**
2380	REDSTONE CREEK	76/11/10	0	7.4	1	640	1	**
2382	NORTH FORK RESERVOIR	76/ 6/16	0	6.9	1	440	1	**
2401	CUBBAGE POND	55/**/**	**	6.2	*	****	*	30
2403	LUMS POND	50/ 8/17	0	6.1	*	****	*	24
		50/ 8/17	3	6.2	*	****	*	23
		74/**/**	0	7.3	2	340	1	**
		75/ 6/19	0	7.3	2	340	1	30
2405	MORRIS MILL POND	55/**/**	**	6.5	*	****	*	28
2406	SILVER LAKE	55/**/**	**	6.0	*	****	*	27
2407	HAVEN LAKE	50/ 8/21	2	3.2	*	****	*	26
		50/ 8/21	0	6.3	*	****	*	24
		50/ 8/21	0	7.2	2	****	*	27
		74/ 8/26	0	7.7	2	459	1	27
		75/**/**	0	7.7	2	540	1	27

STATN	NAME	YR MO DA	Z	PH	M1	ALK	M2	TEM
2408	TRAP POND	55/**/**	**	5.2	*	****	*	26
		74/**/**	0	6.4	2	200	1	**
		75/ 8/20	0	6.4	2	200	1	26
2409	LAKE COMO	52/ 8/ 9	0	6.7	*	****	*	28
		52/ 8/ 9	2	6.5	*	****	*	27
		74/ 8/ 5	0	8.5	2	540	1	26
		75/**/**	0	8.5	2	540	1	26
2410	GARRISONS LAKE	74/ 5/21	0	7.0	2	820	1	18
		75/**/**	0	7.1	2	820	1	18
2411	MASSEYS MILLPOND	55/**/**	**	5.8	*	****	*	27
2412	CHIPMAN POND	55/**/**	0	6.0	2	****	*	29
2415	WYOMING LAKE	53/ 8/ 6	2	6.0	*	****	*	24
		53/ 8/ 6	0	6.3	*	****	*	26
2416	VOSHELL MILL POND	52/ 7/23	2	6.9	*	****	*	23
		52/ 7/23	0	6.8	*	****	*	24
2417	ANDREWS LAKE	55/**/**	**	6.8	*	****	*	30
		74/ 7/22	0	9.2	2	480	1	24
		75/**/**	0	9.2	2	520	1	25
2418	MARSHY HOPE CREEK	74/ 9/11	0	6.5	2	****	*	**
		74/ 9/11	0	6.7	2	****	*	**
2419	KILLENS POND	52/ 6/21	2	6.7	*	****	*	23
		52/ 6/20	0	6.8	*	****	*	25
		74/ 7/30	0	7.1	2	820	1	27
		75/**/**	0	7.1	2	820	1	28
2421	HEARNS POND	55/**/**	0	5.2	2	****	*	29
2502	BLAIR VALLEY LAKE	70/10/ 5	0	7.5	2	1710	1	**
		70/10/ 5	3	7.7	2	1710	1	**
		70/ 0/24	0	8.4	2	1116	1	**
		70/ 6/24	6	6.7	2	1368	1	**
		72/ 7/17	0	9.0	2	1026	1	**
2503	ROCKY GAP RUN	66/ 7/11	0	8.6	1	****	*	22
		70/ 8/10	0	7.7	2	****	*	20

STATN NAME	YR MO DA	Z	PH	M1	ALK	M2	TEM
2504 PINEY CREEK	69/ 9/ 2	0	6.8	2	300	1	••
	77/ 7/ 6	0	7.0	2	••••	•	••
2505 CRABTREE CREEK	74/ 8/13	0	8.5	2	1360	1	••
	74/ 4/30	0	7.2	1	400	1	17
	79/ 7/10	0	7.5	2	1720	1	••
2506 LAKE HABEEB	74/ 8/23	0	7.4	1	120	1	••
	74/ 8/23	18	6.8	1	••••	•	••
2507 FROSTBURG RESERVOIR	68/ 8/ 2	0	7.1	1	408	1	••
	68/ 8/ 2	5	6.6	1	••••	•	••
	77/ 8/18	0	6.3	1	••••	•	••
2508 GUNPOWDER FALLS	68/11/25	0	7.5	2	500	1	••
	70/ 8/10	0	8.5	2	1168	1	••
	70/ 2/ 2	0	7.0	1	••••	•	4
	71/ 6/ 9	0	7.8	2	1026	1	••
	74/ 7/29	0	7.5	1	640	1	••
	75/ 7/ 2	0	7.9	1	494	1	16
	76/ 7/14	0	8.0	2	••••	•	••
	76/ 7/12	0	7.1	1	••••	•	20
	77/ 7/ 7	0	7.5	1	••••	•	23
	78/ 7/18	0	7.3	1	••••	•	18
	80/ 7/14	0	7.3	2	562	1	22
2510 MERRYMAN BRANCH	74/10/ 7	0	7.4	1	••••	•	12
	75/ 9/10	0	7.7	1	600	1	15
	76/10/18	0	7.5	•	••••	•	9
	77/ 8/23	0	7.1	1	••••	•	19
	78/10/30	0	7.3	1	••••	•	10
2511 CHIMNEY BRANCH	75/ 7/28	0	8.2	1	1082	1	20
2512 OWENS CREEK	68/ 7/16	0	7.5	2	1026	1	••
	69/ 7/25	0	7.0	2	855	1	••
	70/ 6/15	0	•••	•	1026	1	••
	73/ 5/29	0	7.5	2	680	1	••
	80/ 8/12	0	7.5	2	900	1	••
	81/ 6/19	0	7.5	2	••••	•	••
2514 HUNTING CREEK	66/ 7/19	0	8.9	1	••••	•	26
	78/ 7/26	0	7.5	1	••••	•	19
	80/ 8/ 6	0	7.5	2	500	1	••
2515 PATUXENT RIVER	70/ 9/10	0	6.8	2	1026	1	••
	73/ 7/27	0	7.0	2	680	1	••
	74/ 7/15	0	7.2	1	340	1	23
	77/ 7/27	0	7.5	2	1160	1	••
	77/ 8/ 4	0	7.5	1	412	1	25
	78/ 9/ 7	0	7.5	2	1160	1	••
	80/ 8/22	0	7.5	2	1020	1	••
	81/ 8/28	0	7.5	2	2205	1	••
2516 HAWKINS RIVER	75/ 6/10	0	6.8	2	680	1	••
	78/11/ 6	0	7.1	1	••••	•	11
2517 GILBERT CREEK	74/ 7/16	0	6.0	1	200	1	28
2522 CYPRESS BRANCH	73/11/20	0	7.3	2	••••	•	10
	76/ 9/15	0	8.2	1	••••	•	20
	80/10/28	0	7.6	1	••••	•	10
2523 WILLISTON LAKE	76/ 5/24	0	7.7	1	••••	•	14
	76/ 8/16	0	7.4	1	••••	•	22
2524 HIGGINS MILL POND	71/ 6/22	0	9.0	2	••••	•	26
	72/ 9/27	0	6.4	2	••••	•	6
2525 ADKINS POND	71/ 7/14	0	5.9	2	••••	•	23
2704 LAKE ALBEMARLE	75/ 6/ 4	0	7.9	2	300	1	26
	75/ 6/ 4	4	6.5	2	360	1	10
	79/ 8/ 6	7	7.3	1	300	1	9
	79/ 8/ 6	0	7.3	1	300	1	29
2705 FLUVANNA RURITAN LAKE	77/ 7/13	0	6.5	1	280	1	31
2706 HOLIDAY LAKE	72/ 5/25	0	7.0	2	••••	•	••
	73/ 5/25	0	6.9	2	••••	•	••
	74/ 5/14	0	7.0	2	••••	•	••
	75/ 5/20	0	6.9	2	••••	•	••
	75/ 7/ 8	0	6.5	2	380	1	••
	75/ 7/ 8	0	6.5	1	380	1	28
	75/ 7/ 8	5	6.2	1	380	1	14
	76/ 6/24	0	7.8	2	••••	•	••
	78/ 7/28	0	7.5	2	••••	•	••
2711 HUNGRY MOTHER LAKE	74/ 7/23	0	6.8	1	500	1	24
	74/ 7/23	5	6.4	1	360	1	15
	74/ 7/23	0	6.8	1	500	1	23
	77/ 7/23	5	6.4	1	360	1	15

```
STATN NAME                        YR MO DA    Z   PH M1   ALK M2 TEM

 2712 CLEAR CREEK                 66/ 5/11    0   7.7 2   4420 1  **
                                  77/ 9/ 7    0   7.9 1   3140 1  25
                                  79/ 8/ 7    0   7.0 1   2100 1  **

 2713 CABIN CREEK                 78/ 5/10    0   7.3 2    300 1  19
                                  80/ 5/29    0   7.3 2    300 1  **

 2717 SLAGLES LAKE                77/ 8/30    0   6.5 2    600 1  **



 2718 LAKE PRINCE                 71/ 6/ 4    0   6.4 2   1000 1  **
                                  71/ 6/ 4    8   6.2 2   1100 1  **
                                  72/ 6/12    0   7.7 2   1200 1  **
                                  72/ 6/12    5   6.7 2   1100 1  **
                                  73/ 6/11    5   6.8 2    900 1  **
                                  73/ 6/11    5   6.8 2    900 1  **
                                  73/ 8/ 7    0   8.5 2   **** *  28
                                  74/ 6/14    0   6.7 2    700 1  **
                                  74/ 6/14    5   6.6 2    800 1  **
                                  76/10/ 6    0   7.3 2   **** *  19
                                  79/ 8/ 6    0   8.4 2   **** *  28

 2720 RESERVOIR ON LICKING C 73/ 5/25    0   6.3 2   **** *  **

                                  72/ 5/24    0   7.3 2   **** *  **

 2724 N. FORK CATOCTIN CREEK  75/ 6/ 2    0   7.0 2   **** *  **
                                  76/ 6/22    0   7.7 2   **** *  **
                                  77/ 6/ 3    0   7.7 2   **** *  **
                                  78/ 9/20    0   8.0 2   **** *  **
                                  79/ 6/21    0   7.6 2   **** *  **
```

APPENDIX C. STATIONS DROPPED FROM CHEMICAL ANALYSIS DISCUSSION

The stations listed below were omitted from the data used for analysis of chemical relationships for various reasons which are coded as follows:

a. poor ionic balance > ±100% disagreement
b. poor theoretical/observed conductivity balance
c. chloride concentration > 500 µeq/l
d. conductivity > 200 µS/cm
e. double endpoint alkalinity > 1000 µeq/l
f. color > 30 Pt-Co units

Station	Elimination Code					
	a	b	c	d	e	f
2101			x	x	x	
2120				x	x	
2121	x					
2123	x					
2125	x					
2128	x					
2132	x					
2140	x					
2144		x				
2151					x	
2152			x	x	x	
2201			x	x	x	
2204			x			
2206				x		
2210				x	x	
2211				x	x	
2214			x	x		
2215						x
2224		x				
2334	x					
2337					x	
2343			x			
2349				x		
2350					x	
2352				x	x	
2353			x		x	

(continued)

Station	Elimination Code a	 b	 c	 d	 e	 f
2354					x	
2362			x	x	x	
2363			x		x	
2365			x			
2374					x	
2376						x
2377						x
2406			x	x		
2411				x		
2503					x	
2507				x		
2510			x			
2511					x	
2513				x	x	
2522						x
2523						x
2524						x
2525						x
2603				x	x	
2627					x	
2628					x	
2630	x					
2634			x	x		
2635	x					
2637	x					
2640			x			
2701					x	
2702				x	x	
2712					x	
2718						x
2803	x					
2903				x	x	
2905					x	
2906				x	x	

The net result of these removals is to decrease the number of stations used for discussion of the chemical data from 278 to 218; a 22% decrease. Removals by state were:

New York	11 of 46	(24%)
New Jersey	8 of 31	(26%)
Pennsylvania	14 of 88	(16%)
Delaware	2 of 21	(10%)
Maryland	9 of 24	(38%)
West Virginia	8 of 23	(35%)
Virginia	4 of 24	(17%)
North Carolina	1 of 10	(10%)
Tennessee	3 of 11	(27%)
	--	--
Total	60 of 278	(22%)

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REPORT DOCUMENTATION PAGE

1. REPORT NO. Biological Report 80(40.19)

2.

3. Recipient's Accession No

4. Title and Subtitle

Vulnerability of Selected Lakes and Streams in the Middle Atlantic Region to Acidification: A Regional Survey

5. Report Date June 1985

6.

7. Author(s) Arnold, D.E., R. W. Light, and E.A. Paul

8. Performing Organization Rept. No

9. Performing Organization Name and Address

Pennsylvania Cooperative Fish and Wildlife Research Unit
Ferguson Building
University Park, PA 16802

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Division of Biological Services, Eastern Energy and Land Use
Team, Box 705, Kearneysville, WV 25430

13. Type of Report & Period Covered Final

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words) In conjunction with a similar study in the New England States, 278 lakes and streams in the 9 Middle Atlantic States (New York, New Jersey, Pennsylvania, Maryland, Delaware, Virginia, West Virginia, North Carolina, and Tennessee) were surveyed. Primary objectives were to document the sensitivity of these waters to acidification and to test the validity of available models and classifications for predicting their acidification. The study results indicate that a large number of relatively undisturbed waters in the Middle Atlantic States are either already acidified or are susceptible to acidification. A large portion of the waters sampled in the region have decreased in pH, alkalinity, or both in recent years. Alkalinity is probably the most accurate and useful predictor of sensitivity to acidification. About 49% of the unpolluted, comparatively undeveloped waters sampled were sensitive to acidification on the basis of having alkalinity less than 200 ueq/l or having underlying bedrock of low acid neutralizing capacity. The calcium-pH model of Henriksen is a fairly accurate predictor of lake pH and indicated that about 28% of the waters were acidified. Few of the waters showed high concentrations of aluminum, and there was only one case of a potentially toxic aluminum/pH combination.

17. Document Analysis a. Descriptors

Acidification, pH, alkalinity, aluminum, water chemistry, geology

b. Identifiers/Open-Ended Terms

acid rain, acidified waters, acid deposition, water quality, stress, calcium concentrations

c. COSATI Field/Group

18. Availability Statement: Unlimited

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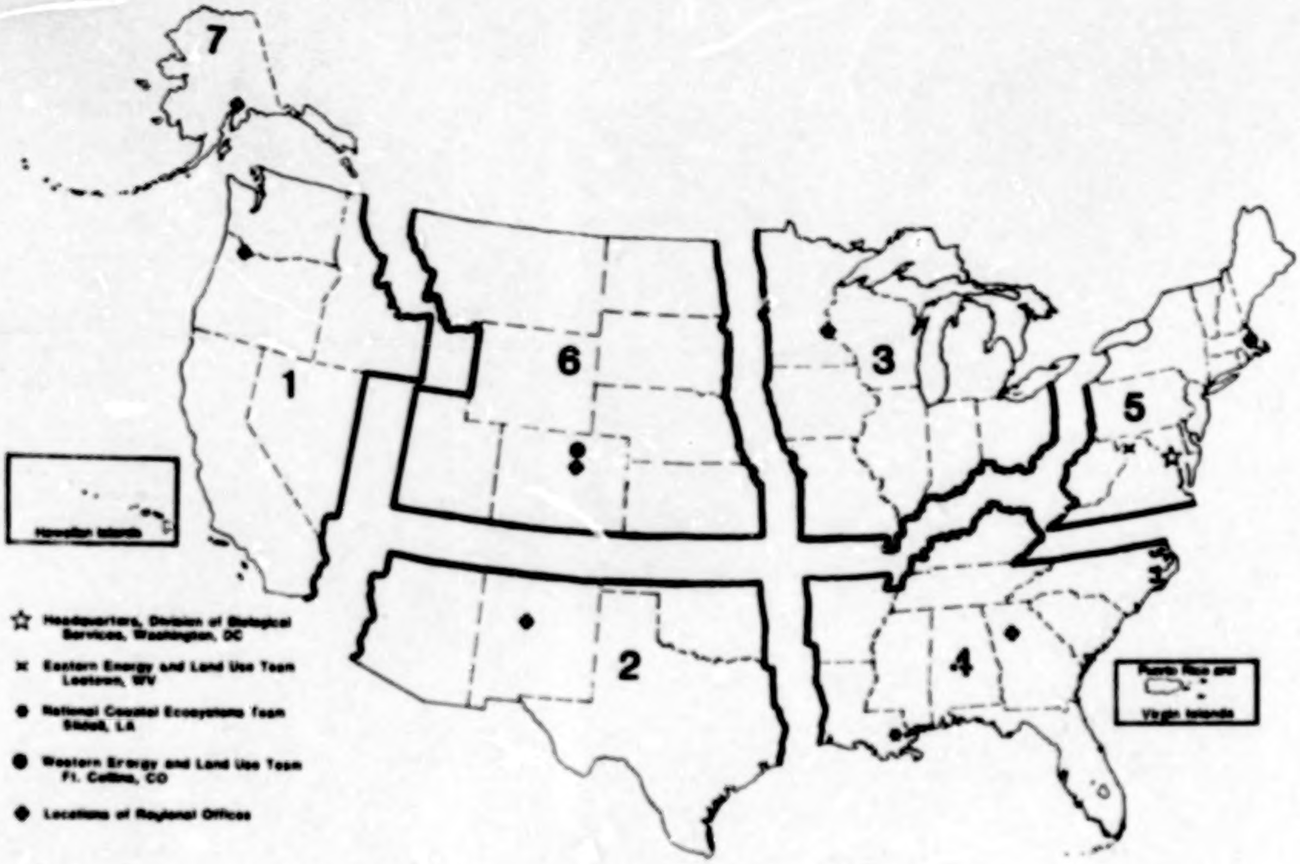
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March 3, 1849

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